TABLE IV

Assumed RVP psi	T V/L20 Computer °F.	T V/L20 Linear °F.
9	131.6	132.9
9.5	129.5	130.8
10	127.5	128.8
10.5	125.6	126.7
11	123.9	124.7
11.5	122.2	122.6

Since the measured value for T V/L20 for the 6/86 Honolulu fuel is 126.2°F., the corresponding estimated RVP by the computer and linear methods (about 10.5 psi) is very close to the 10.6 psi that Ms. Minner obtained with the nomogram method.

In view of the foregoing, and the data and analysis in Ms. Minner's affidavit, I would not put any faith in the 6.70 psi RVP value for the 6/86 Honolulu fuel in Attachment A, and I believe that no one skilled in the fuel art would trust that value. I am convinced, and believe that one skilled in the fuel art would be convinced, that the data for the 6/86 Honolulu fuel are in error and that the error in all probability lies with the RVP analysis.

FURTHER AFFIANT SAYS NOT.

Robert S. Russell

Robert L. Russell

Subscribed and sworn to before me this 25th day of March, 1994.

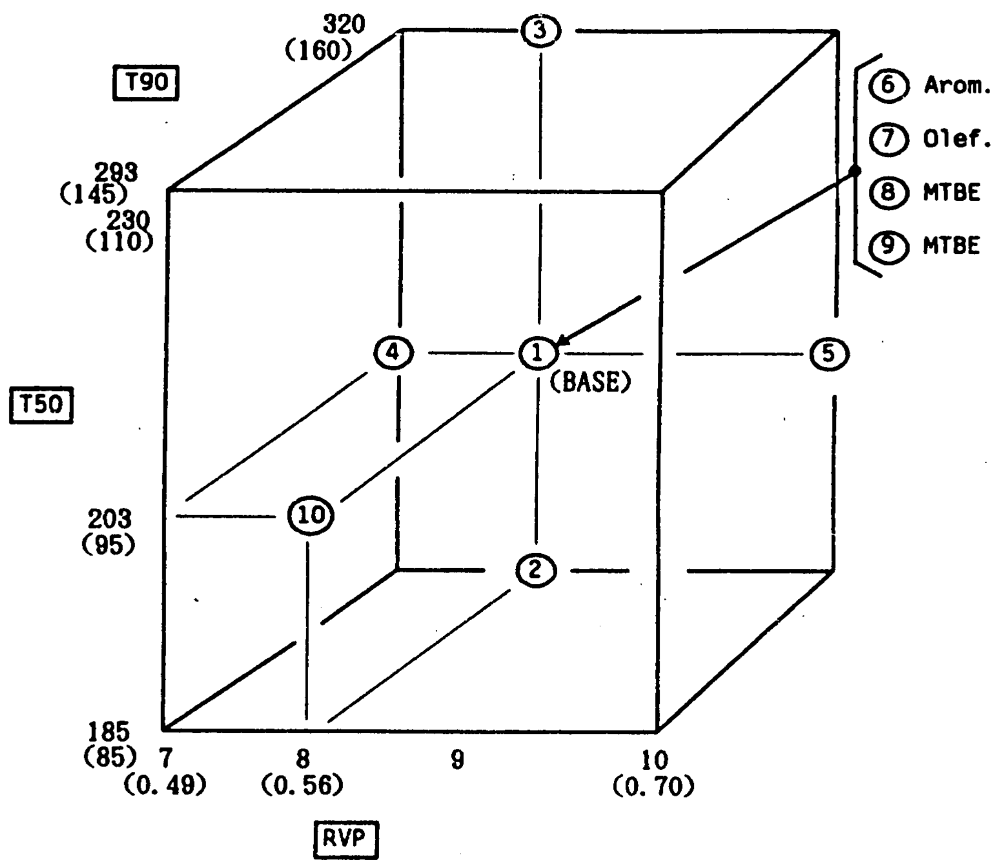
PAT LANCE
COMM. #981656
NOTARY PUBLIC • CALIFORNIA
ORANGE COUNTY
My Comm. Expires Feb. 1, 1997

Pat Lance

Notary Public in and for the
State of California
County of Orange
My Commission expires FEBRUARY 1, 1997

$T_{50} \uparrow \equiv$ emissions $\uparrow$

From Toyota
7-17-90



Test Gasoline Matrix

ATTACHMENT T1

EXTRA Copy

PTO 1449 FORMS FOR

PUBLICATIONS SUBMITTED WITH

IDS No. 3, SECTION A

SN 08/077,243 JESSUP ET AL.

FILED JUNE 14, 1993

INFORMATION DISCLOSURE STATEMENT	ATTY. DOCKET NO.0290112	SERIAL NO. 08/077,243
	APPLICANT Jessup et al.	
	FILING DATE June 14, 1993	GROUP 1109

U. S. PATENT DOCUMENTS

*Exam Initial		DOCUMENT NUMBER							DATE	NAME	CLASS	SUB CLASS	Filing Date
	AA	2	2	0	4	2	1	5	06/11/40	Greensfelder et al.			
	AB												
	AC												
	AD												
	AE												
	AF												
	AG												
	AH												
	AI												
	AJ												
	AK												

FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER							PUBLICATION DATE	COUNTRY	CLASS	SUB CLASS	TRANS. YES	TRANS. NO
	AL													
	AM													
	AN													
	AO													
	AP													

OTHER DISCLOSURES (Including Author, Title, Date, Pertinent Pages, Place of Publication, Etc.)

	AR		CRC Project No. CM-79-71, "Analysis of 1971 Road Rating Data: Unleaded Gasolines in 1971 Cars, Phase II: 1970-71 CRC Road Rating Program," Coordinating Research Council, Inc., June, 1973.
	AS		CRC Report No. 454, "Effect of Altitude Changes on Octane Number Requirement of Late Model Cars," October, 1973.
	AT		CRC Report No. 455, "Evaluation of a High Temperature Driveability Test Procedure," June 1973, pages 1-3, 8-10, 39, & 40.

Examiner: Date Considered

*EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

INFORMATION DISCLOSURE STATEMENT (Use several sheets if necessary)	ATTY. DOCKET NO. 0290112	SERIAL NO. 08/077,243
	APPLICANT Jessup et al.	
	FILING DATE June 14, 1993	GROUP 1109

OTHER DISCLOSURES (Including Author, Title, Date, Pertinent Pages, Place of Publication, Etc.)

	R		CRC Report No. 477, "1973 CRC Fuel Rating Program Part 1: Road Octane Performance in 1973 Model Cars, February 1975.
	S		CRC Report No. 494, "1975 CRC Fuel Rating Program: Road Octane Performance in 1975 Model Cars, October 1977.
	T		CRC Report No. 510, "1978 Fuel Rating Program: Road Octane Performance in 1978 Model Cars, August 1979, pages 1-3, 17, & 18.
	U		CRC Report No. 578, "Effect of Volatility and Oxygenates on Driveability at Intermediate Ambient Temperatures," March 1992.
	V		"Initial Findings of the 1989 CRC Cold-Start and Warm-Up Driveability Program," Yakima, Washington, CRC Project No. CM-118-89, June 1990, with cover letter dated June 13, 1990, by Beth Evans, Technical Project Coordinator to the Members of the CRC-Automotive Committee and the CRC-Volatility Group, June 13, 1990.
	W		SAE Paper No. 710138, "Passenger Car Driveability in Cool Weather," by J. D. Benson et al., 1971.
	X		SAE Paper No. 720700, "Mathematical Expressions Relating Evaporative Emissions from Motor Vehicles Without Evaporative Loss-Control Devices to Gasoline Volatility," by W. F. Biller et al., 1972.
	Y		SAE Paper No. 720932, "The Effect of Gasoline Volatility on Exhaust Emissions," by P. J. Clarke, 1972.
	Z		SAE Paper No. 720933, "Driveability Testing on a Chassis Dynamometer," by R. J. Wahrenbrock et al., 1972.
	RR		SAE Paper No. 730474, "An Evaluation of the Performance and Emissions of a CRF Engine Equipped with a Prechamber," by D. B. Wimmer et al., 1973.
	SS		SAE Paper No. 730593, "Fuel Effects on Oxidation Catalysts and Catalyst-Equipped Vehicles," by A. H. Neal et al., 1973.

Examiner: Date Considered

*EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

INFORMATION DISCLOSURE STATEMENT (Use several sheets if necessary)	ATTY. DOCKET NO. 0290112	SERIAL NO. 08/077,243
	APPLICANT Jessup et al.	
	FILING DATE June 14, 1993	GROUP 1109

OTHER DISCLOSURES (Including Author, Title, Date, Pertinent Pages, Place of Publication, Etc.)

	R		SAE Paper No.780611, "Fuel Volatility Effects on Driveability of Vehicles Equipped with Current and Advanced Fuel Management Systems," by C. R. Morgan et al., 1978.
	S		SAE Paper No. 780651, "Hot Weather Volatility Requirements of European Passenger Cars," by R. F. Becker et al., 1978.
	T		SAE Paper No. 780949, "The Effects of Refinery Gasoline Components on Road Octane Quality," by R. E. Burtner et al., International Fuels & Lubricants Meeting, Royal York, Toronto, Nov. 13-16, 1978.
	U		SAE Paper No. 801352, "Evaluation of MTBE Gasoline by Japanese Passenger Cars," by Shintaro Miyawaki et al., 1980.
	V		SAE Paper No. 841386, "Hot and Cold Fuel Volatility Indexes of French Cars: A Cooperative Study of the GFC Volatility Group," by Le Breton et al., 1984.
	W		SAE Paper No. 902132, "Use of Ethyl-t-Butyl Ether (ETBE) as a Gasoline Blending Component," C. M. Shiblom et al., 1990.
	X		NIPER--143-PPS-86/1, "Motor Gasolines, Summer 1985," by C. L. Dickson et al., Work performed by the American Petroleum Institute and the U. S. Department of Energy, National Institute for Petroleum and Energy Research, Bartlesville, Oklahoma, June 1986.
	Y		"Petroleum Refinery Engineering," by W. L. Nelson, Fourth Edition, McGraw Hill Book Company, Inc., 1958, pages 34 and 138.
	Z		"Future Automotive Fuels," by Ellis, Automotive Engineering, June 1972, pp. 36-41
	RR		
	SS		

Examiner:	Date Considered

*EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

PTO 1449 FORMS FOR 12

PUBLICATIONS SUBMITTED WITH

IDS No. 3, SECTION B

SN 08/077,243 JESSUP ET AL.

FILED JUNE 14, 1993

INFORMATION DISCLOSURE STATEMENT (Use several sheets if necessary)	ATTY. DOCKET NO. 0290112	SERIAL NO. 08/077,243
	APPLICANT Jessup et al.	
	FILING DATE June 14, 1993	GROUP 1109

OTHER DISCLOSURES (Including Author, Title, Date, Pertinent Pages, Place of Publication, Etc.)

	O	✓	CRC Project No. CM-125-78, "Performance Evaluation of Alcohol-Gasoline Blends in 1980 Model Automobiles," July 1982, page C-13.
	P	✓	SAE Paper No. 710136, "The Effect of Gasoline Volatility on Emissions and Driveability," by P. J.
	Q	✓	SAE Paper No. 710364, "Effects of Fuel Factors on Emissions," by S. S. Sorem, 1971.
	R	✓	SAE Paper No. 730616, "Gasolines for Low-Emission Vehicles, by J. C. Ellis, 1973.
	S	✓	SAE Paper No. 740694, "Fuels and Emissions -- Update and Outlook, 1974." by R. W. Hurn et al., 1974.
	T	✓	SAE Paper No. 750419, "Methanol-Gasoline Blends Performance in Laboratory Tests and in Vehicles," by A. W. Crowley et al., 1975.
	U	✓	SAE Paper No. 780653, "The Hot-Fuel Handling Performance of European and Japanese Cars," by B. D. Caddock et al., 1978.
	V	✓	SAE Paper No. 852132, "Gasoline Vapor Pressure Reduction--an Option for Cleaner Air," by R. F. Stebar et al., 1985.
	W	✓	BERC/RI-76/15, "Experimental Results Using Methanol and Methanol/Gasoline Blends as Automotive Engine Fuel," by J. R. Allsup, Published by Bartlesville Energy Research Center, Energy Research and Development Administration, Bartlesville, Oklahoma January 1977, pages 1-7.
	X	✓	"Reformulated Gasoline for Clean Air, An ARCO Assessment" by K. L. Boekhaus et al., for "Roads to Alternative Transportation Fuels" 2nd Biennial U.C. Davis Conference on Alternative Fuels, July 12, 1990.
	Y	✓	"The Impact on Fuels of the 1990 Clean Air Act Amendments," by C. A. Lieder, presented at the NPR National Fuels and Lubricants Meeting, Nov. 1-2, 1990, Houston, Texas.
	Z	✓	"Motor Fuels, Performance and Testing," William A. Gruse, Reinhold Publishing Corp., 1967, page 104.

Examiner: Date Considered

*EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

PTO 1449 FORMS FOR

PUBLICATIONS SUBMITTED WITH

IDS No. 3, SECTION C

SN 08/077,243 JESSUP ET AL.

FILED JUNE 14, 1993

INFORMATION DISCLOSURE STATEMENT	ATTY. DOCKET NO. 0290112	SERIAL NO. 08/077,243
	APPLICANT Jessup et al.	
	FILING DATE June 14, 1993	GROUP 1109

U. S. PATENT DOCUMENTS

*Exam Initial		DOCUMENT NUMBER	DATE	NAME	CLASS	SUB CLASS	Filing Date
	AA						
	AB						
	AC						
	AD						
	AE						
	AF						
	AG						
	AH						
	AI						
	AJ						
	AK						

FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	PUBLICATION DATE	COUNTRY	CLASS	SUB CLASS	TRANS. YES	TRANS. NO
	AL							
	AM							
	AN							
	AO							
	AP							

ABSTRACTS OF OTHER DISCLOSURES (Including Author, Title, Date, Pertinent Pages, Place of Publication, Etc.)

	AR	Publication No. 05-179263, GASOLINE, Laid Open July 20, 1993, Japanese Application No. 03-358562 filed 12/27/91.
	AS	Publication No. 03-263493, LEAD-FREE HIGH-OCTANE GASOLINE, Laid Open Nov. 22, 1991, Japanese Application No. 02-63537 filed 03/14/90.
	AT	Publication No. 03-229796, FUEL OIL COMPOSITION, Laid Open Oct. 11, 1991, Japanese Application No. 02-24005 filed 02/02/90.

Examiner: Date Considered

*EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

INFORMATION DISCLOSURE STATEMENT (Use several sheets if necessary)	ATTY. DOCKET NO. 0290112	SERIAL NO. 08/077,243
	APPLICANT Jessup et al.	
	FILING DATE June 14, 1993	GROUP 1109

ABSTRACTS OF OTHER DISCLOSURES (Including Author, Title, Date, Pertinent Pages, Place of Publication, Etc.)

	R		Publication No. 01-234497, LEAD-FREE HIGH OCTANE VALUE GASOLINE, Laid Open Sept. 19, 1989, Japanese Application No. 63-59587 filed 03/14/88.
	S		Publication No. 01-131299, FUEL COMPOSITION FOR USE IN GASOLINE ENGINE, Laid Open May 24, 1989, Japanese Application No. 63-247245 filed 09/29/88.
	T		Publication No. 01-9293, CLEAR GASOLINE, Laid Open Jan. 12, 1989, Japanese Application No. 62-162966 filed 06/30/87.
	U		Publication No. 63-317593, UNLEADED REGULAR GASOLINE, Laid Open Dec. 26, 1988, Japanese Application No. 62-154189 filed 06/20/87.
	V		Publication No. 63-317592, PRODUCTION OF HIGH-POWERED FUEL OIL, Laid Open Dec. 26, 1988, Japanese Application No. 62-153837 filed 06/19/87.
	W		Publication No. 63-317591, HIGH-POWERED FUEL OIL, Laid Open Dec. 26, 1988, Japanese Application No. 62-153836 filed 06/19/87.
	X		Publication No. 63-317590. UNLEADED AND HIGH-OCTANE GASOLINE, Laid Open Dec. 26, 1988, Japanese Application No. 62-153026 filed 06/19/87.
	Y		Publication No. 63-289094, LEAD-FREE, HIGH-OCTANE GASOLINE, Laid Open Nov. 25, 1988, Japanese Application No. 62-123129 filed 05/20/87.
	Z		Publication No. 61-176694, GASOLINE COMPOSITION, Laid Open Aug. 8, 1986, Japanese Application No. 60-17120 filed 01/31/85.
	RR		Publication No. 61-166884, FUEL COMPOSITION FOR GASOLINE ENGINE, Laid Open Jul. 28, 1986, Japanese Application No. 61-14308 filed 01/24/86.
	SS		Publication No. 61-16985, MANUFACTURE OF UNLEADED GASOLINE OF HIGH OCTANE VALUE, Laid Open Jan. 24, 1986, Japanese Application No. 59-137525 filed 07/3/84.

Examiner:	Date Considered

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INFORMATION DISCLOSURE STATEMENT (Use several sheets if necessary)	ATTY. DOCKET NO. 0290112	SERIAL NO. 08/077,243
	APPLICANT Jessup et al.	
	FILING DATE June 14, 1993	GROUP 1109

ABSTRACTS OF OTHER DISCLOSURES (Including Author, Title, Date, Pertinent Pages, Place of Publication, Etc.)

	R		Publication No. 61-16984, MANUFACTURE OF GASOLINE MAINLY FROM HYDROCARBON OF BOILING POINT LOWER THAN 220°C. SUCH AS PETROLEUM NAPHTHA OR NAPHTHA-CRACKED GASOLINE, Laid Open Jan. 24, 1986, Japanese Application No. 59-138668 filed 07/04/84.
	S		Publication No. 60-130684, FUEL COMPOSITION, Laid Open Jul. 12, 1985, Japanese Application No. 58-237881 filed 12/19/83.
	T		Fuel and Energy Abstracts, May 1990, Oil Gas J., May 1989, 87 (20), 35-40.
	U		Fuel and Energy Abstracts, May 1990, Pure Appl. Chem., 1989, 61, (8), 1373-1378.
	V		Fuel and Energy Abstracts, March 1990, Oil Gas J., April 1989, 87, (16) 44-48.
	W		Fuel and Energy Abstracts, September, 1989, Chem. Aust., 1989, 56, (3), 77-79.
	X		Fuel and Energy Abstracts, September, 1989, Erdoel, Erdgas, Kohle, 1988, 104, (9), 368-371. (In German)
	Y		Fuel and Energy Abstracts, March, 1989, Erdoel Kohle, Erdas, Petrochem., Dec. 1988, 41, (12), 491, 496.
	Z		
	RR		
	SS		

Examiner:	Date Considered

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PTO 1449 FORMS FOR

PUBLICATIONS SUBMITTED IN

SN 08/077,243 JESSUP ET AL.

FILED JUNE 14, 1993 AS TO REFERENCES

IN PARENT APPLICATION, NOW

U.S. PATENT 5,288,393

INFORMATION DISCLOSURE STATEMENT	ATTY. DOCKET NO. 0290112	SERIAL NO.
	APPLICANT PETER J. JESSUP ET AL.	
	FILING DATE	GROUP

U. S. PATENT DOCUMENTS

*Exam Initial		DOCUMENT NUMBER							DATE	NAME	CLASS	SUB CLASS	Filing Date
	AA	3	7	5	3	6	7	0	8/21/73	Strang et al.	44	432	
	AB	3	9	5	5	9	3	8	5/11/76	Graham et al.	44	305	
	AC	3	9	8	8	1	2	2	10/26/76	Rosenthal et al.	44	452	
	AD	4	2	1	4	8	7	6	7/29/80	Garth et al.	44	404	
	AE	4	2	1	5	9	9	7	8/5/80	Sandy	44	367	
	AF	4	3	1	2	6	3	6	1/26/82	Singerman	44	447	
	AG	4	3	8	7	2	5	7	6/7/83	Burns	585	14	
	AH	4	3	8	8	0	8	1	6/14/83	Burns	44	443	
	AI	4	3	1	9	9	8	1	3/16/82	Singerman	44	447	
	AJ	4	5	0	1	5	9	6	2/26/85	Burns	44	341	
	AK	4	6	9	9	6	2	9	10/13/87	Croudace et al.	44	429	

FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER							PUBLICATION DATE	COUNTRY	CLASS	SUB CLASS	TRANS. YES	TRANS. NO
	AL		2	1	3	1	3	6	5/23/52	Australia (Spijker)	208	17		
	AM													
	AN													
	AO													
	AP													

OTHER DISCLOSURES (Including Author, Title, Date, Pertinent Pages, Place of Publication, Etc.)

	AR	
	AS	
	AT	

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	APPLICANT JESSUP ET AL.	
	FILING DATE	GROUP

U. S. PATENT DOCUMENTS

*Exam Initial		DOCUMENT NUMBER							DATE	NAME	CLASS	SUB CLASS	Filing Date
	BA	4	7	3	7	1	5	9	4/12/88	Phillips	44	419	
	BB	4	7	4	3	2	7	3	5/10/88	Croudace et al.	44	418	
	BC	4	7	7	3	9	1	6	9/27/88	Croudace et al.	44	440	
	BD	4	8	1	2	1	4	6	3/14/89	Jessup	585	14	
	BE	4	8	2	4	5	5	2	4/25/89	Nagasawa	208	17	
	BF	4	8	4	4	7	1	7	7/4/89	Croudace et al.	44	418	
	BG												
	BH												
	BI												
	BJ												
	BK												

FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER							PUBLICATION DATE	COUNTRY	CLASS	SUB CLASS	TRANS. YES	TRANS. NO
	BL													
	BM													
	BN													
	BO													
	BP													

OTHER DISCLOSURES (Including Author, Title, Date, Pertinent Pages, Place of Publication, Etc.)

	BR		
	BS		
	BT		

Examiner: Date Considered

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TEST FUELS FOR REFORMULATED GASOLINE STUDY ~ target specs.

Fuel No.	RON	(MON)	RVP psi	T50 °F	T90 °F	Arom. vol.%	Olef. vol.%	MTBE vol.%	Comments
1	97	87	8.0 (0.56)	203 (95)	320 (160)	30	12	0	Base Case
2	97	87	8.0	185 (85)	320	30	12	0	T50 Reduction
3	97	87	8.0	239 (110)	320	30	12	0	T50 Increase
4	97	87	7.0 (0.49)	203	320	30	12	0	RVP Reduction
5	97	87	10.0 (0.70)	203	320	30	12	0	RVP Increase
6	97	87	8.0	203	320	15	12	0	Arom. Contents Reduction
7	97	87	8.0	203	320	30	0	0	Olef. Contents Reduction
8	97	87	8.0	203	320	30	12	7	MTBE Blend (Medium Conc.)
9	97	87	8.0	203	320	30	12	15	MTBE Blend (Maximum Conc.)
10	97	87	8.0	203	293 (145)	30	12	0	T90 Reduction
			x	x	x	x	x	x	

$\boxed{\text{AKI} = 92}$

x = variables.

driveability
FTP emissions

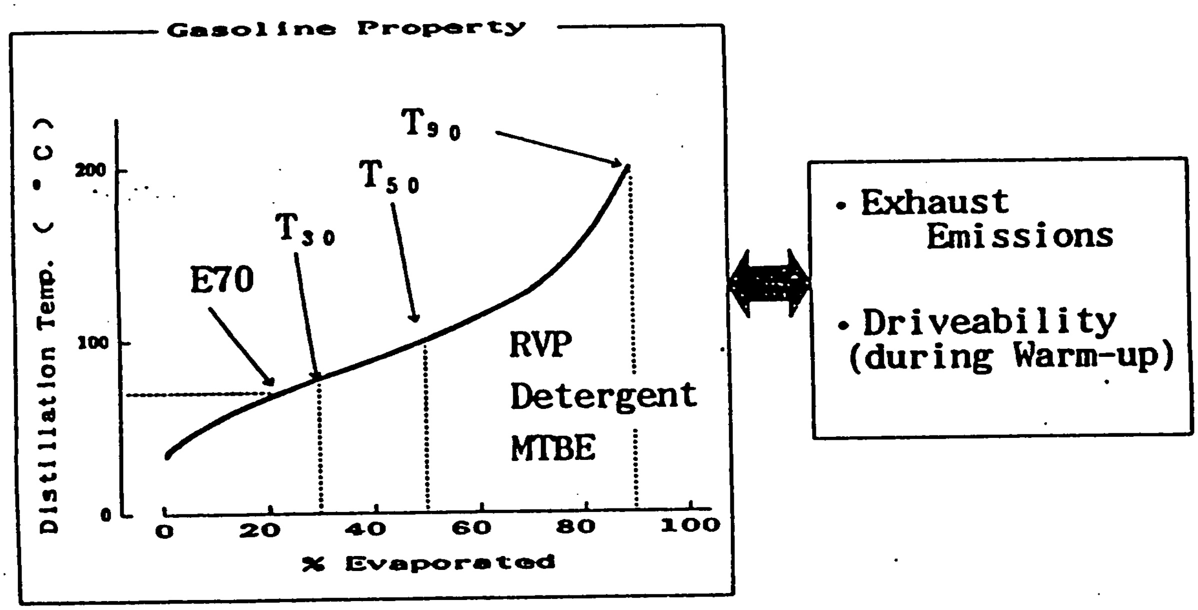
Toyota wants tight control of T_{50} in reformulated gasolines.

T_{50} 85→100 °C
~ pushing @ CARB

Saw 50% change in emissions by changing T_{50}.

EFFECT OF GASOLINE PROPERTY ON EXHAUST EMISSIONS AND DRIVEABILITY

TOYOTA MOTOR CORPORATION
OCTOBER, 1990



Extra Copy

1. Driveability Test

* Hesitation during Warm-up Period
    - Engine Bench Test
      Engine Response Time
    - Vehicle Test --- Field Evaluation

* Engine Startability Test
    - Low Temperature Test Cell --- 20° C, -25° C

2. Exhaust Emission Test

Tailpipe Emissions, FTP

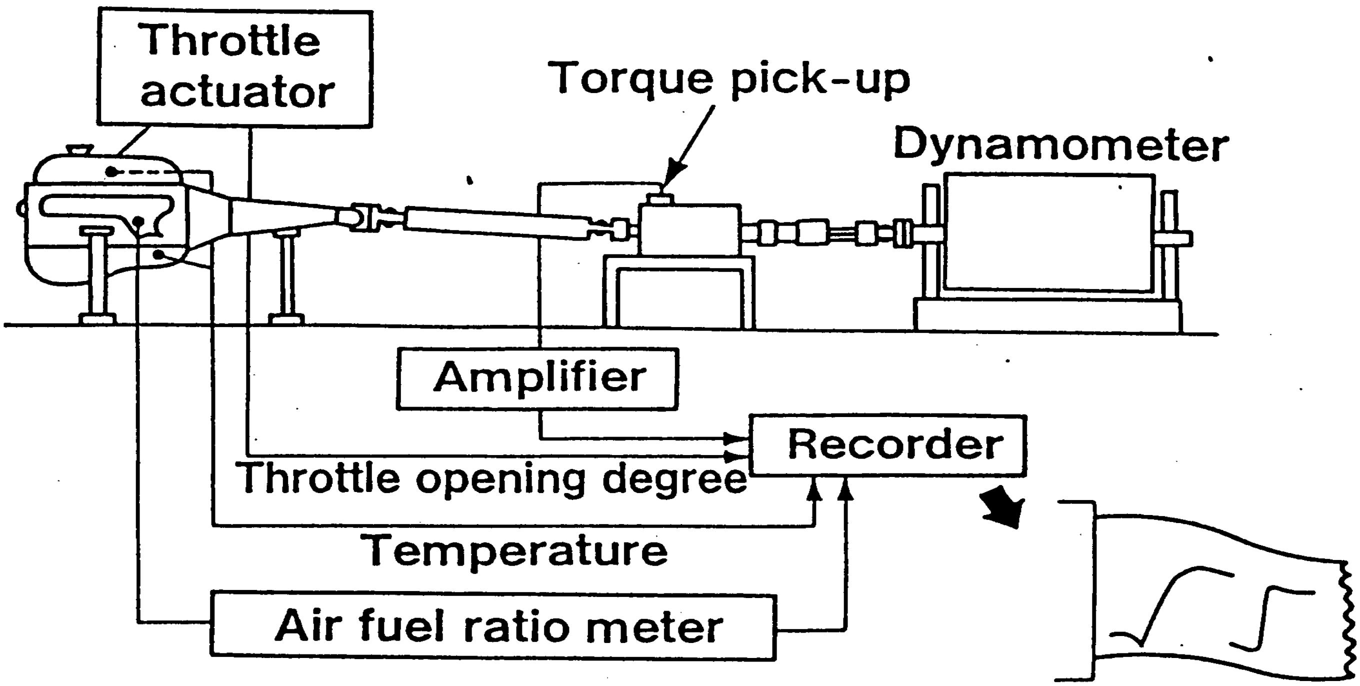
Study of the Effect

of

Gasoline Property

on

Engine Response

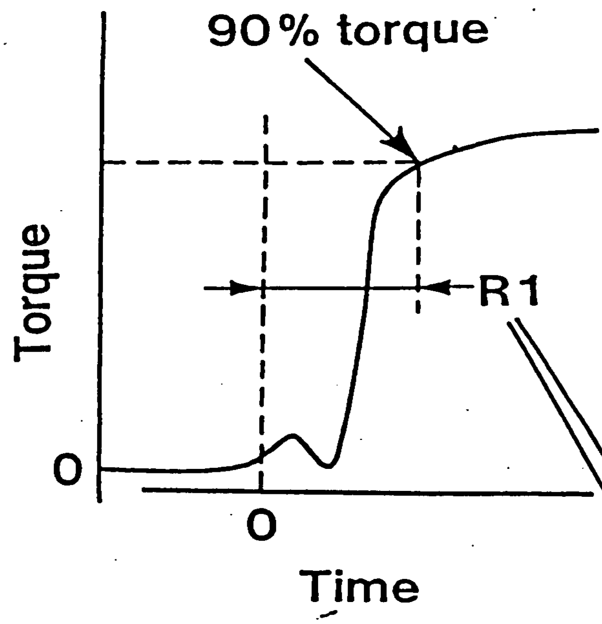


TOYOTA | Experimental apparatus | No. 5

Gasoline No.	1	2	3	----	10	11	12
RVP kPa	71.5	65.7	71.5	----	83.3	84.8	46.0
E70 %	32.3	27.8	32.9	----	33.4	35.7	20.5
T10 °C	48.0	50.5	47.0	----	42.0	41.0	59.5
T50 °C	91.5	99.0	91.0	----	100.0	94.0	110.0
T90 °C	152.0	159.0	152.0	----	162.5	163.0	161.0
Arom. %	28.5	28.0	38.5	----	47.0	38.0	32.8

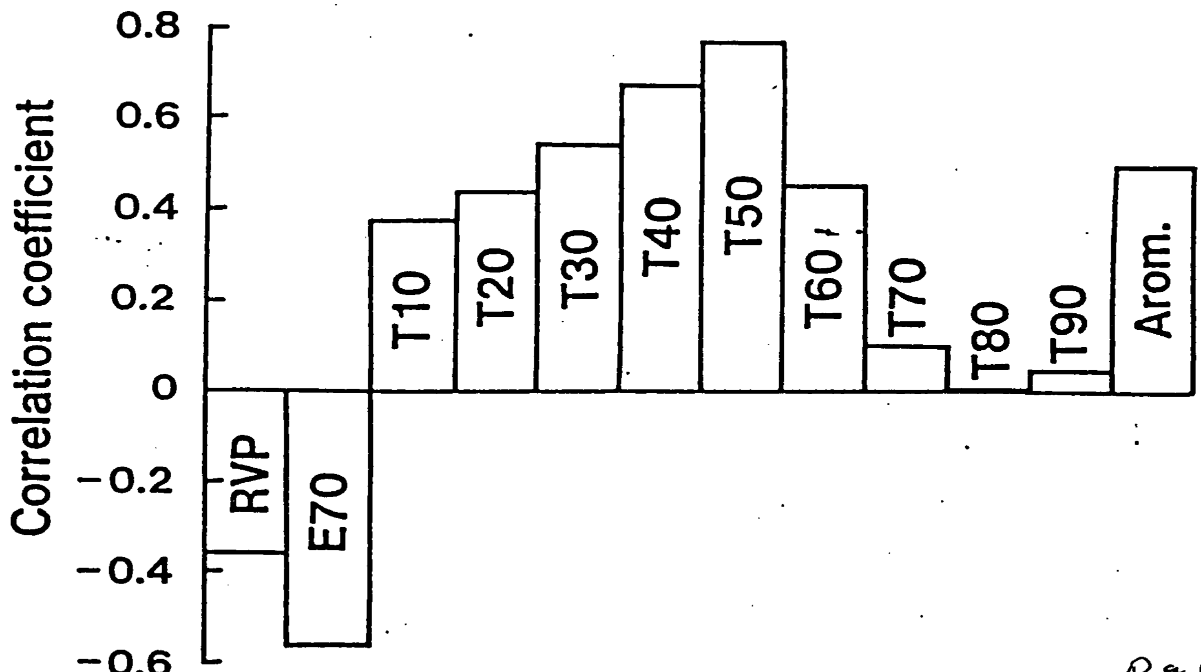
(no oxygenate)

TOYOTA | Test gasolines | No. 8



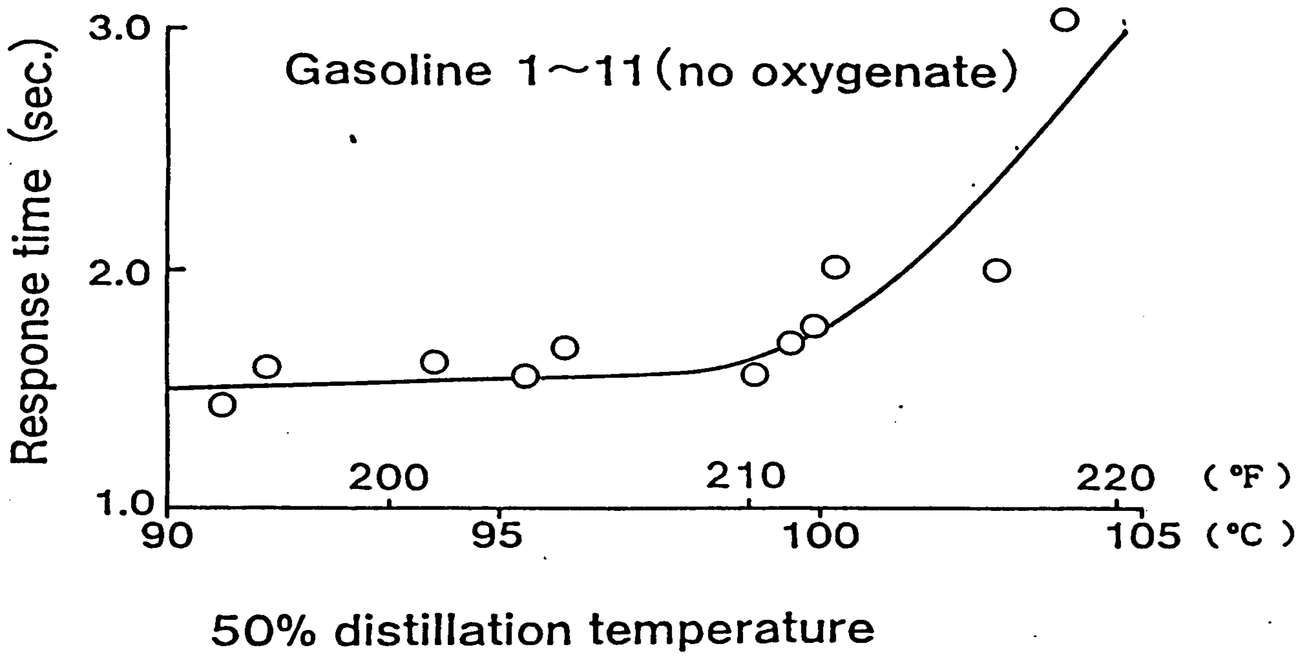
Gasoline	1	2
RVP kPa	71.5	65.7
E 70 %	32.3	27.8
T 10 °C	48.0	50.5
T 50 °C	91.5	99.0
T 90 °C	152.0	159.0
Arom. %	28.5	28.0
Response time (sec.)	R_1	R_2

TOYOTA	Response time and gasoline characteristics	No. 9

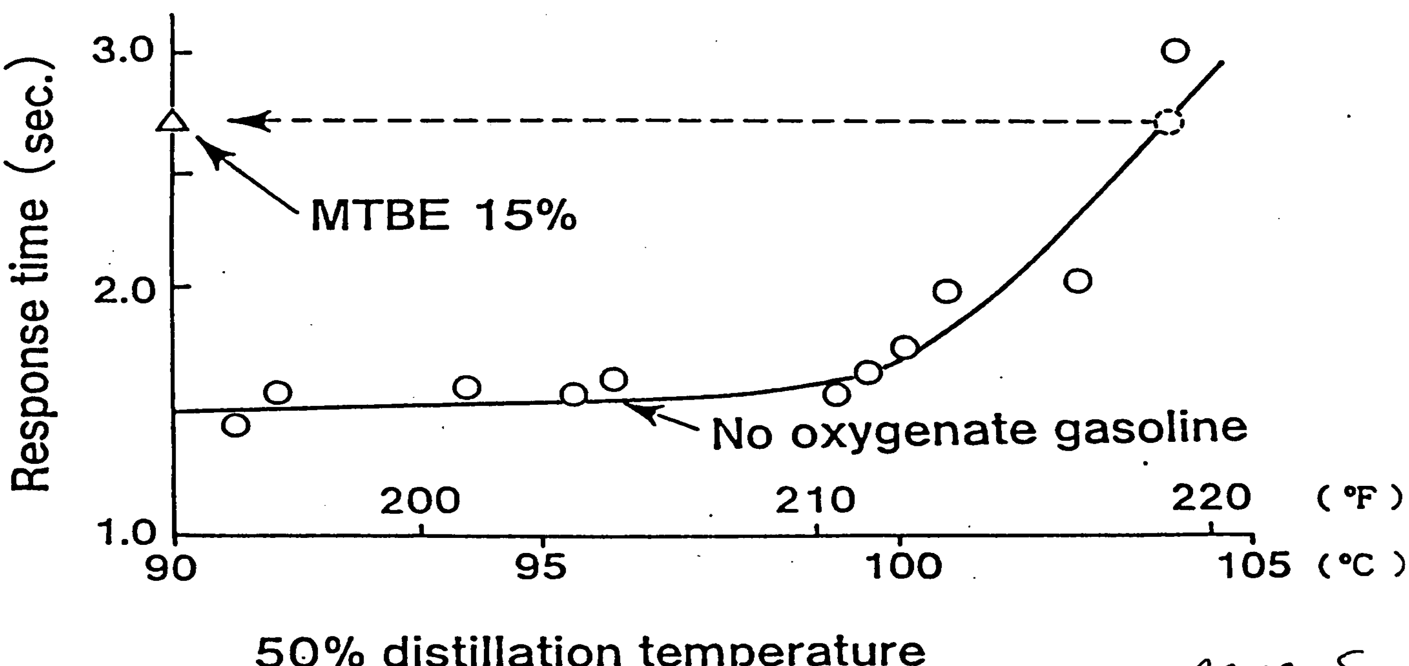


page 4

TOYOTA	Comparison of correlation	No. 10

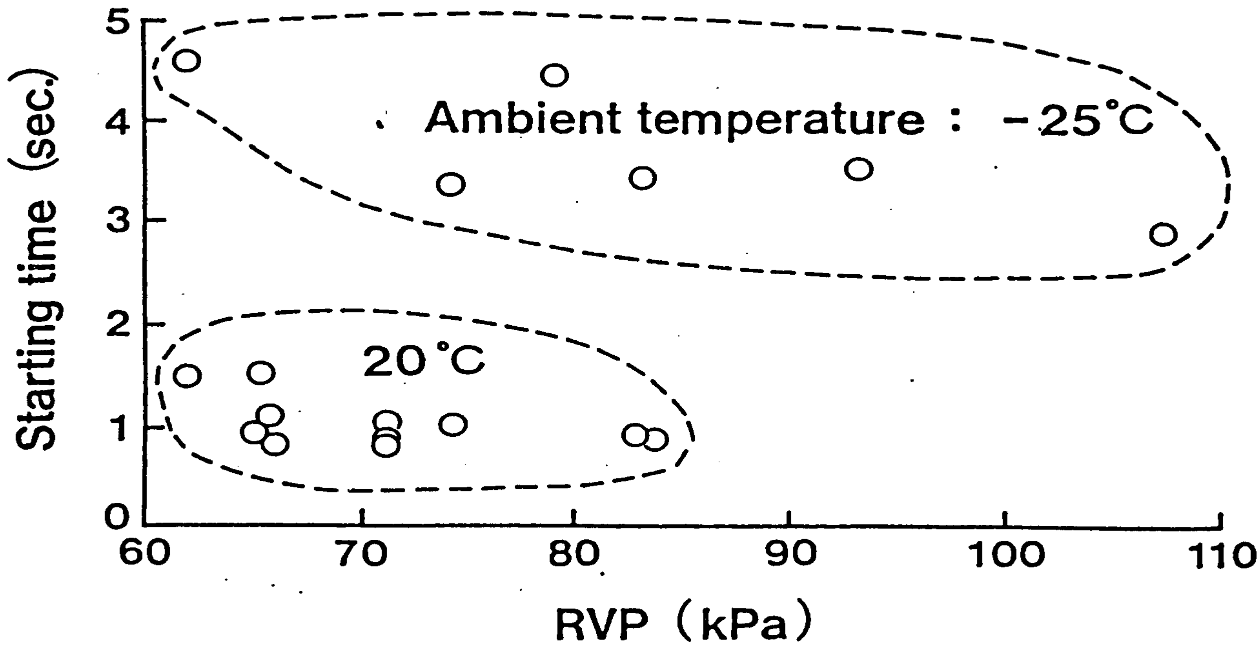


TOYOTA	Effect of 50% distillation temperature	No. 11



page 5

TOYOTA	Effect of MTBE blended gasoline	No. 20



TOYOTA	Effect of RVP on engine start	No. 14

<u>Results of Driveability Test</u>

1. The Middle Range of Gasoline Distillation Temperature Strongly Affects Warm-up Driveability.
   T_{50} Can Be Used as One Indication of Warm-up Driveability.

2. RVP Has a Small Effect on Warm-up Driveability in the Range between 60～90 KPa (8.6～13.0 psi).

3. RVP Regulation Will not Deteriorate Vehicle Driveability, if T_{50} is controlled in a proper range.

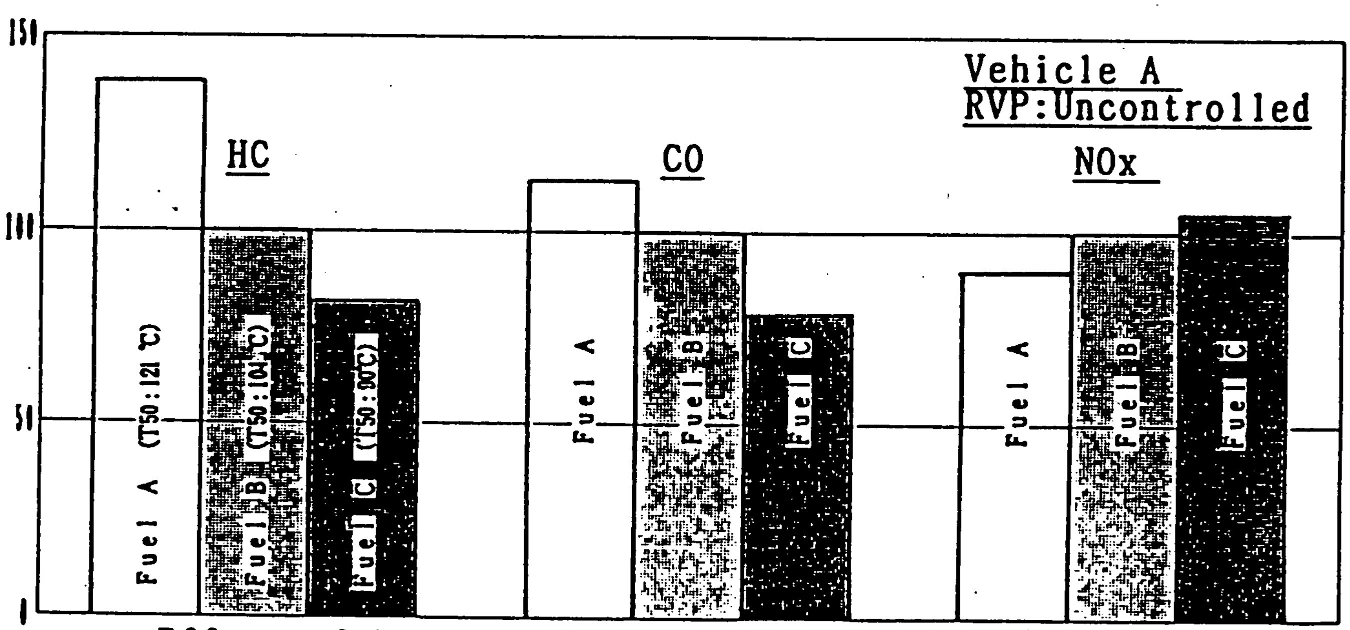
Study of the Effect

of

Distillation Characteristics

on

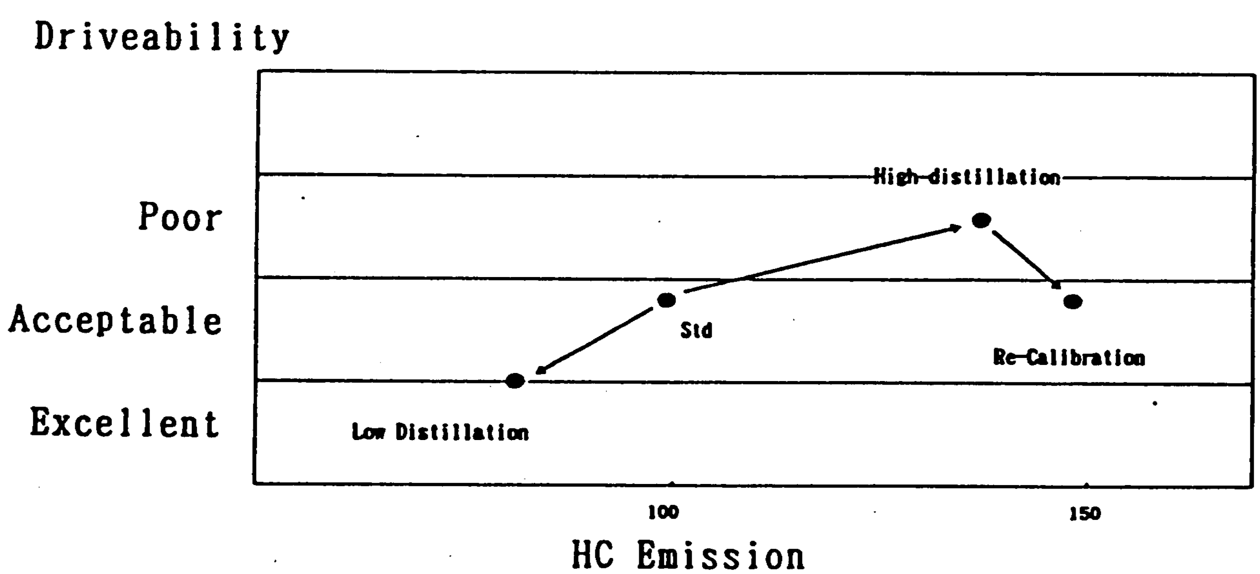
Exhaust Emissions



Effect of T_{50} on Exhaust Emissions (Fuel B=100)

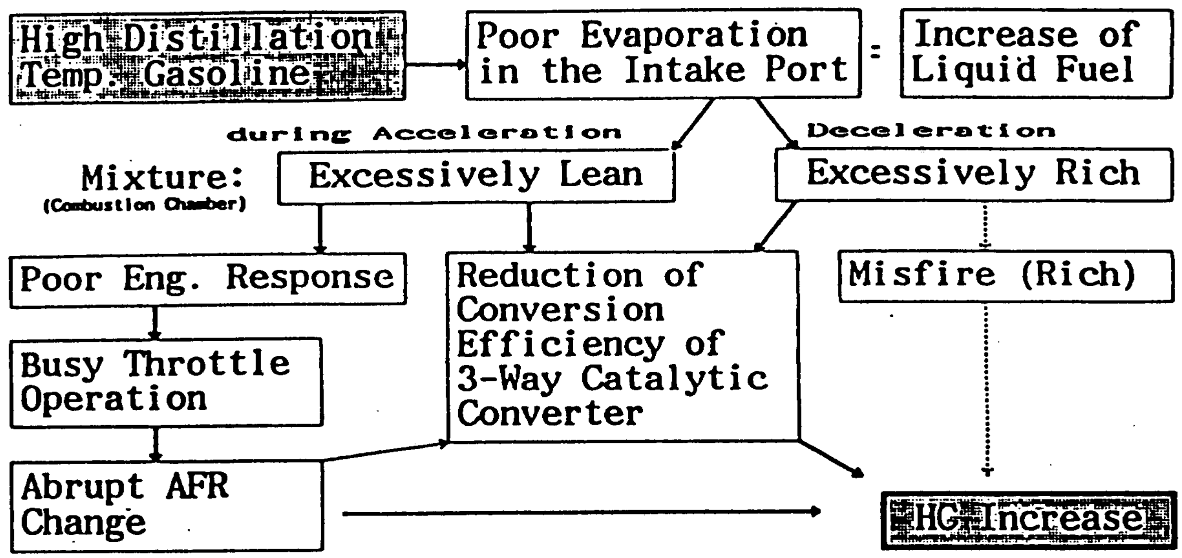
Comparison of Fuel Characteristics(A)

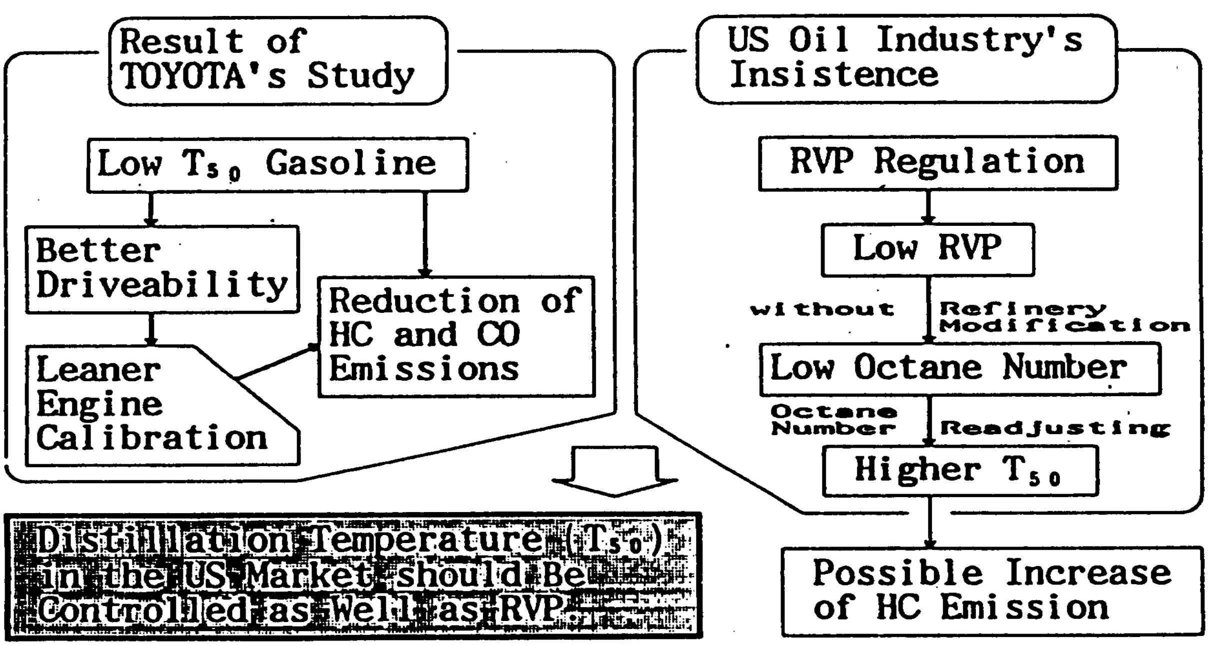
Fuel Characteristics		Fuel A	Fuel B	Fuel C
Density(g/mℓ@15℃)		0.766	0.743	0.734
RVP (kgf/cm²)		0.55	0.62	0.845
RON		97.2	91.5	91.4
MON		88.4	82.5	82.3
Distillation (℃)	IBP	34.5	31.5	27.5
	10%	58.5	53.0	43.0
	50%	121	104	90.0
	90%	170	157	161
	EP	209	176	176
Aromatics (vol%)		39.3	31.8	30.5
Olefins (vol%)		9.0	5.1	14.5



Effect of Gasoline Distillation Characteristics on Exhaust Emmission and Driveability

MECHANISM OF HC INCREASE WITH HIGH T_{50} GASOLINE





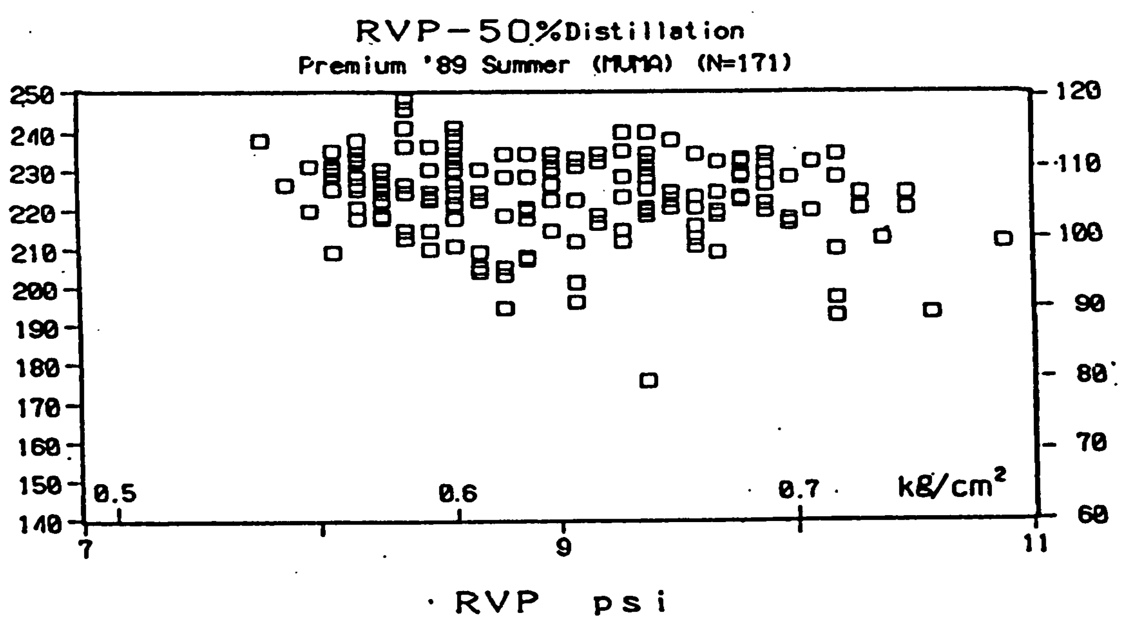
Distribution

of

Gasoline Characteristics

in

the US Market



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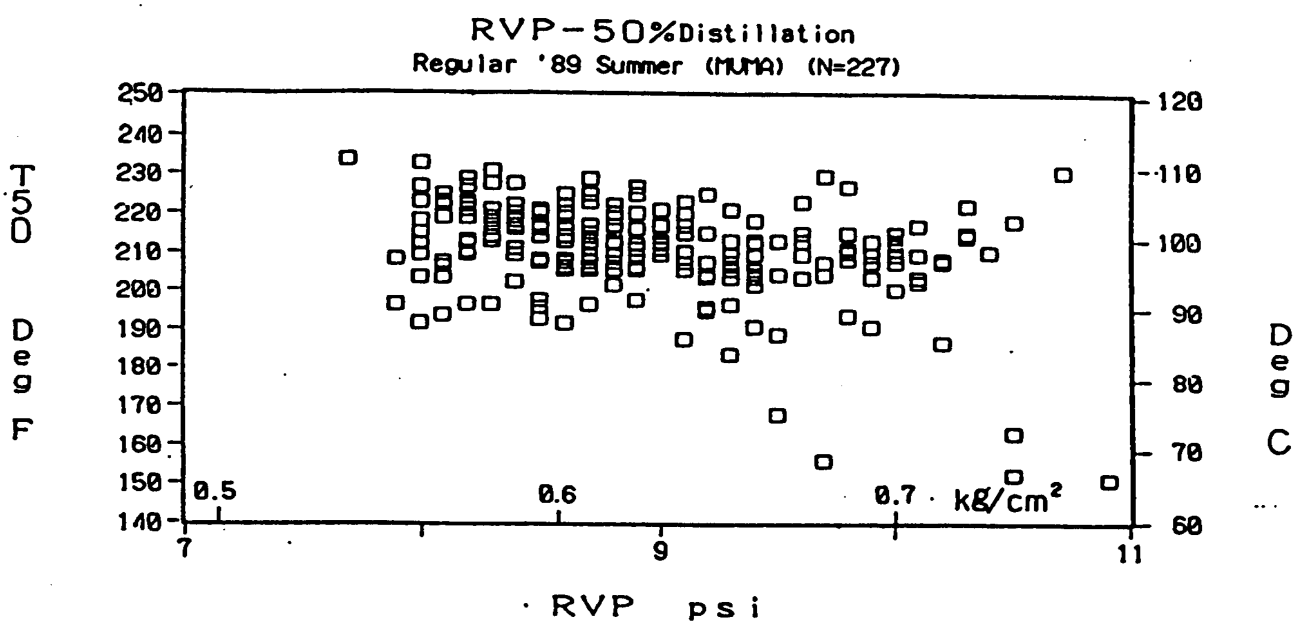
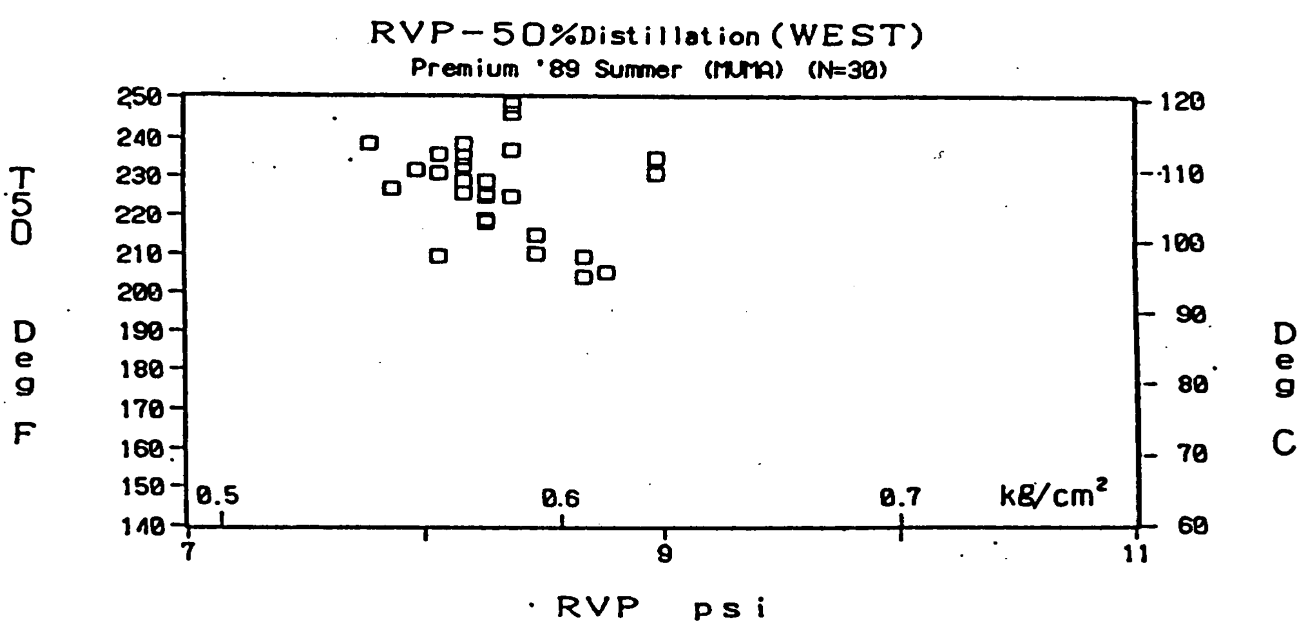
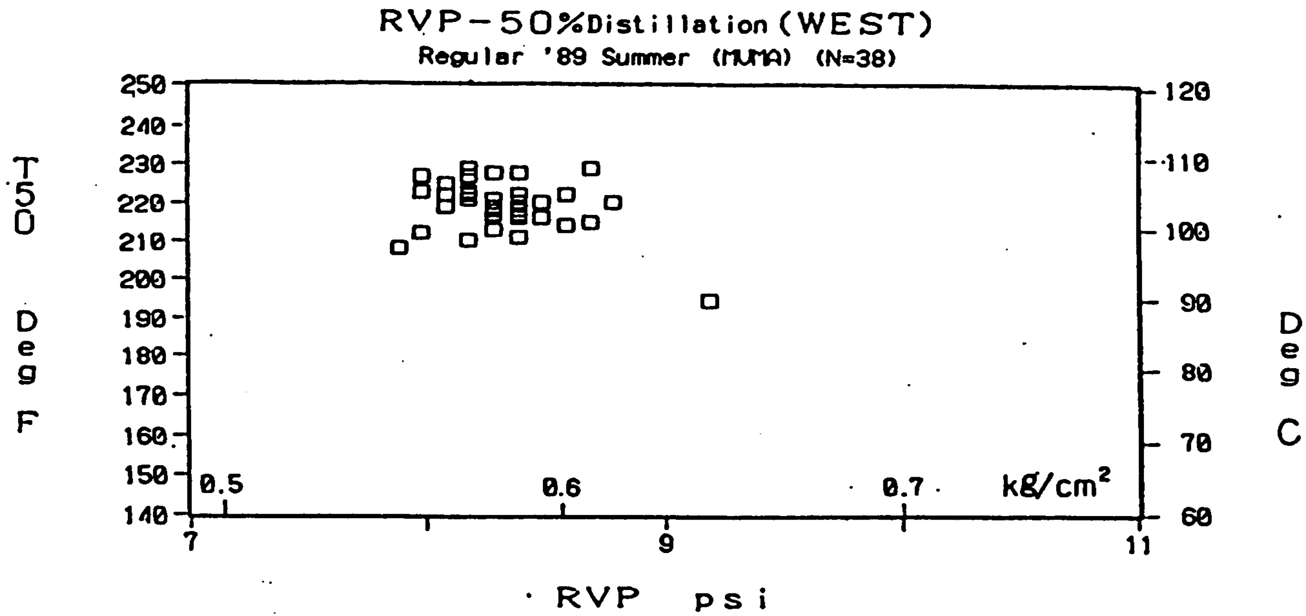
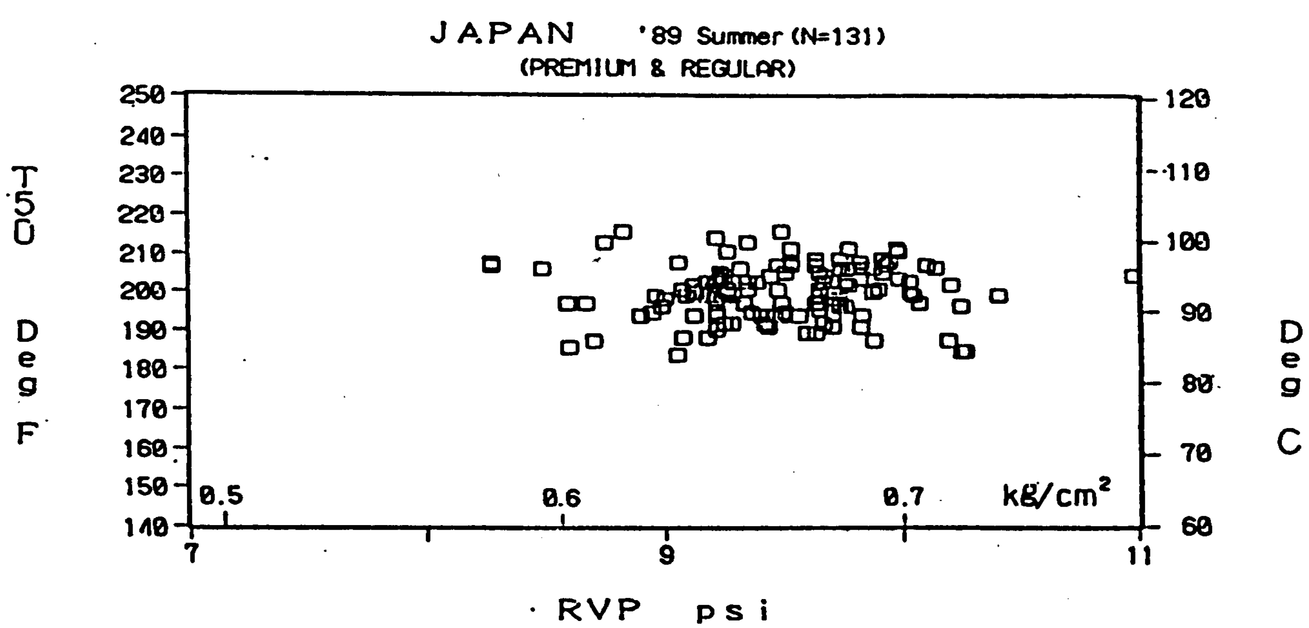

RVP-50%Distillation
Regular '89 Summer (MUMA) (N=227)
T50 Deg F
Deg C
250
240
230
220
210
200
190
180
170
160
150
140
120
110
100
90
80
70
60
0.5
0.6
0.7
kg/cm²
7
9
11
RVP psi


RVP-50%Distillation (WEST)
Premium '89 Summer (MUMA) (N=30)
T50 Deg F
Deg C
250
240
230
220
210
200
190
180
170
160
150
140
120
110
100
90
80
70
60
0.5
0.6
0.7
kg/cm²
7
9
11
RVP psi


RVP-50%Distillation (WEST)
Regular '89 Summer (MUMA) (N=38)
T50 Deg F
Deg C
250
240
230
220
210
200
190
180
170
160
150
140
120
110
100
90
80
70
60
0.5
0.6
0.7
kg/cm²
7
9
11
RVP psi


JAPAN '89 Summer (N=131)
(PREMIUM & REGULAR)
T50 Deg F
Deg C
250
240
230
220
210
200
190
180
170
160
150
140
120
110
100
90
80
70
60
0.5
0.6
0.7
kg/cm²
7
9
11
RVP psi

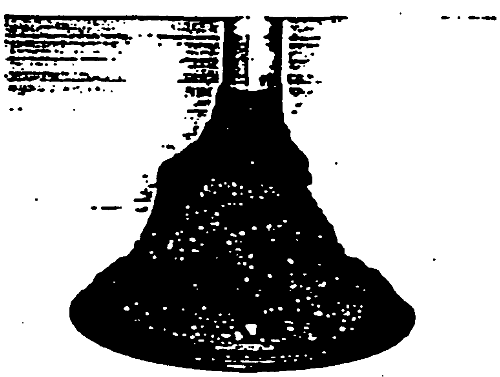
Study of the Effect

of

Intake Valve Deposit (IVD)

on

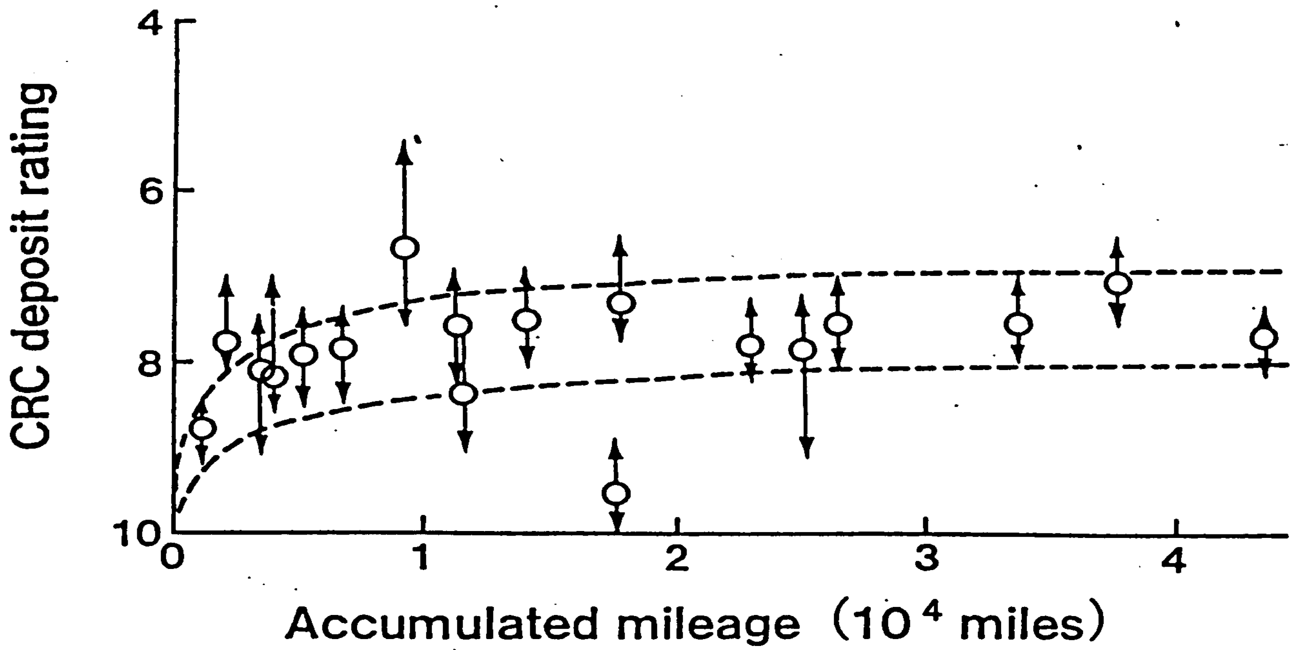
Exhaust Emissions and Driveability



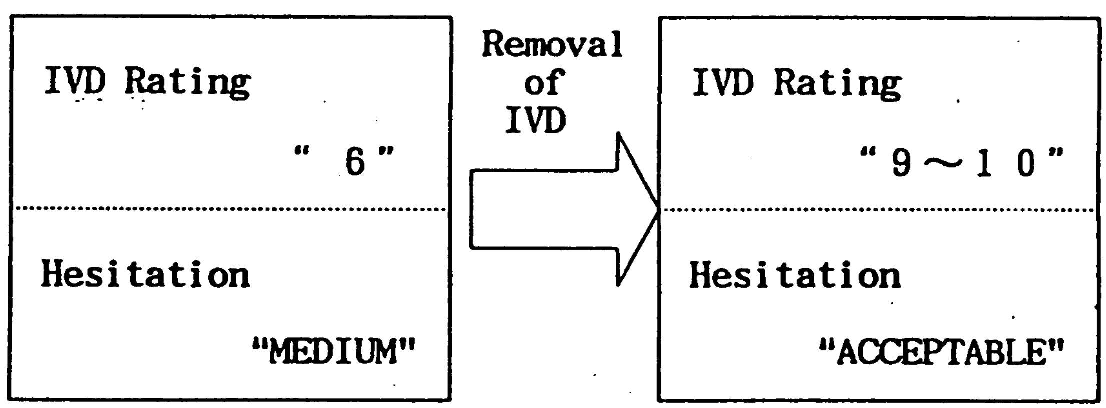
Test I

Test II

APPEARANCE OF DEPOSIT



TOYOTA	IVD level in the US market	No. 26



Effect of IVD on Vehicle Driveability

IVD Rating "6"

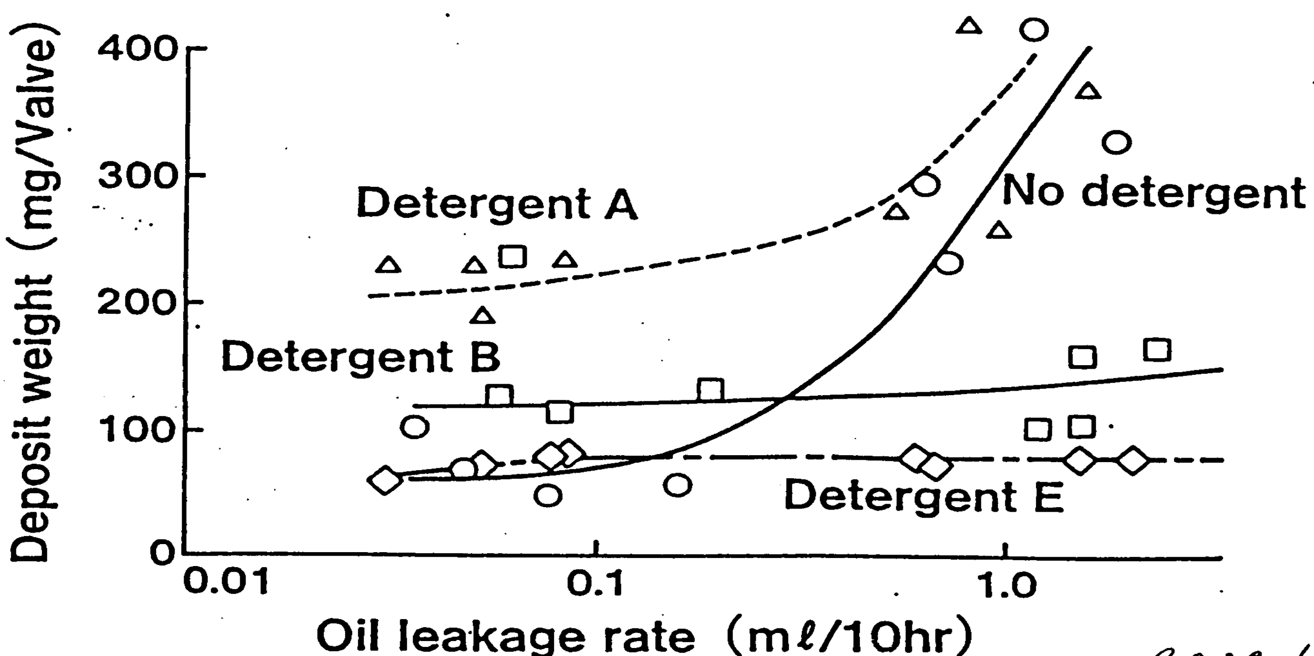
HC	149
CO	101
NOx	127

Removal of IVD →

IVD Rating "9～10"

HC	100
CO	100
NOx	100

Effect of IVD on Exhaust Emissions



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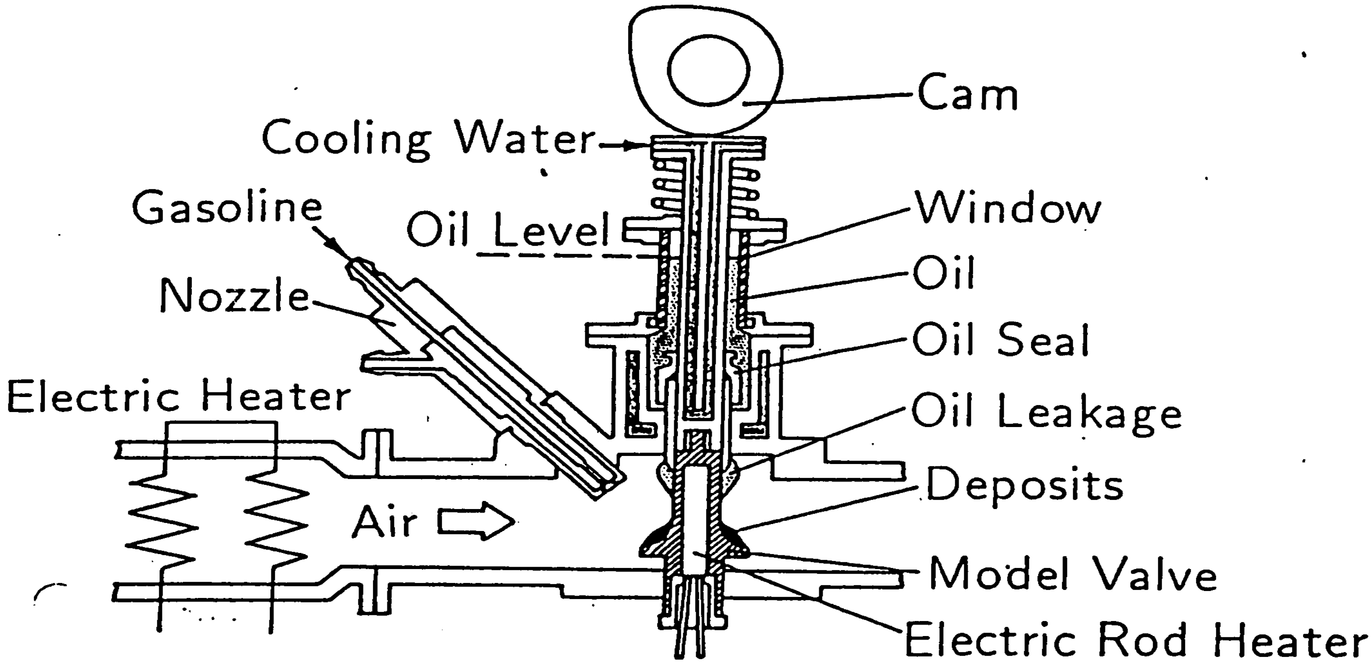


TOYOTA C. R&D, INC.

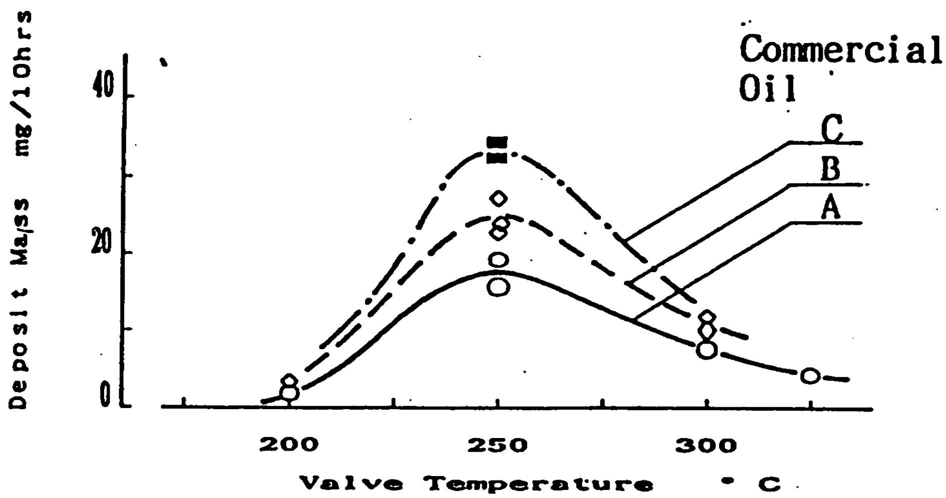
Structure of Simulator

Results of Our Study on the Intake Valve Deposit

(1) IVD Mainly Originates from Engine Oil.

(2) Poor Quality Gasoline Detergents Accelerate
Oil Deterioration, and This Increases IVD Formation.

(3) Oil Quality Affects IVD Formation.
(See Next Slide)



Effect of Oil Quality on Intake Valve Deposit

CONCLUSION

(1) The middle Range of Gasoline Distillation Temperature affects Warm-up Driveability, and HC and CO Emissions.

(2) A T_{50} Decrease of 10- 15° C Produces 15-25 % Reduction of HC and CO Emissions.

(3) RVP Regulation may Encourage High T_{50} Gasoline in the US Market and result in Increased HC and CO Emissions, IF the Distillation Temperatures Are Not Controlled.

(4) It Is Hoped the Range of T_{50} Distribution in the US Will Be Reduced. This Will Contribute to Improved Air Quality.

(5) MTBE-Blended Gasoline Shows Poor Engine Response Characteristics Compared with HC-Type Gasolines.

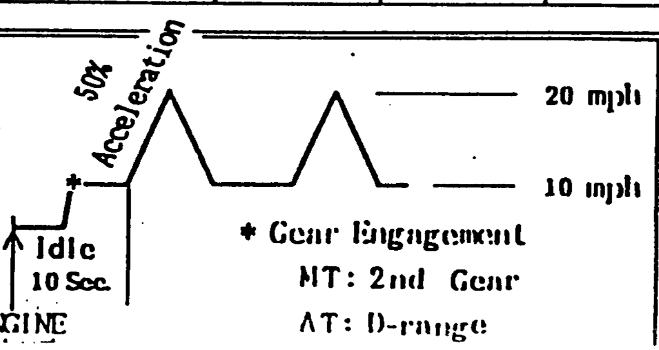
(6) IVD Deteriorates HC and CO Emissions. Engine Oil and Fuel Detergent Quality also Affect IVD.

Survey of Driveability of USA Cars

Test Vehicle

Model	Year	Engine	Displacement (l)	Fuel System	Transmission	Mileage
T_1	'87	L 4	2.0	F I	M T	1130
T_2	'89	L 6	3.0	F I	A T	3440
A	'87	V 6	3.8	F I	A T	898
B	'88	L 4	2.3	F I	A T	2830
C	'88	L 4	2.2	F I	M T	869
D	'88	V 6	2.7	F I	M T	3230

Driving Schedule for Driveability Test



Vehicle Model	Gasoline T50 (°C)	Water Temp (°C) *	Test Cycle No. 1	2	3	4	5	Comment
T1	102	9						
	109	7	Trace					
		30						
	119	9	Heavy	Moderate	Moderate			Back Fire
		30			Moderate			Back Fire
T2	119	7						
A	109	17						Smoke
B	102	5	Moderate					
		18						
	109	5	Heavy	Trace				Back Fire
		30						
	119	9	Heavy	Heavy	Trace	Trace	Trace	Engine Stall
C	109	1		Moderate				Back Fire
	119	5	Heavy	Moderate	Moderate	Moderate		
D	119	18						

* Water Temperature at Engine Start

Hesitation

Heavy Moderato Trace None

Driveability Test Results

Summary of the Driveability Test

* We believe Customers in the USA Suffer Poor Driveability :
  - Caused by High Distillation Gasoline
  - Deteriorated by IVD Formation during warm-up Period
  - Particularly in the West Coast Area

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Effects of Gasoline Composition on Exhaust Emissions and Driveability

H. Hoshi, M. Nakada, M. Kato, M. Okada and N. Kayanuma
Toyota Motor Corp.

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Effects of Gasoline Composition on Exhaust Emissions and Driveability

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ABSTRACT

A study of the effects of changes in gasoline composition is one area to explore in our effort to reduce tailpipe emissions from vehicles. However, affects on vehicle performances should also be considered from the perspective of practical useage.

In this paper, the influence of gasoline composition (aromatics) ,volatility, and MTBE blending on engine outlet and tailpipe emissions are discussed ,in particular,forcusing on distillation properties which have a close relationship to driveability.

Under stable driving conditios and without a catalitic converter, the effects of gasoline volatility is small, while aromatics in gasoline affect exhaust HC and NOx emissions. MTBE has a leaning effect on the engine intake air/fuel mixture.

During a transient driving cycle, a high gasoline 50% distillation temperature causes poor driveability, as a result, HC emissions increase.

1. Introduction

One of the most significant challenges that the automobile faces today is the enviroment. This will necessitate further efforts to reduce automobile exhaust emissions in the United States. Past efforts to reduce exhaust emissions were based primarily on improving the automobile. Another approach to this problem is by altering fuel composition including the introduction of unleaded gasoline, reduction of RVP, and blending oxygenates. It is necessary to increase efforts to reduce exhaust emissions by altering gasoline composition, along with further efforts to improve the automobile.

Various studies have been made over many years concerning the relationship between the properties of gasoline and the performance and driveability of vehicle (1,2,3). However, there have been few studies on the relationship beetween exhaust emissions, particularly of recent vehicles having a computer-controlled fuel injection engine management system, and the properties of gasoline, such a hydrocarbon composition, addition of oxygen-containing compounds, and volatility (4).

It is important to take into account the relationship between exhaust emissions, vheicle driveability, and fuel consumption, to clarify gasoline properties which would be desirable in the reduction of exhaust emission (5).

To initiate this study, the influences of composition, volatilitis and MTBE blending on exhaust emissions were investigated at a costant engine speed. By using a transient mode as practical use condition, the relationship between exhaust emissions and vehicle driveability was evaluated.

2. Fuel properties and exhaust emissions

First, to determine the effects of the gasoline properties on exhaust emissions, a test was conducted under the constant engine speed conditions and without a catalitic converter. Gasoline physical properties, composition, volatility,and MTBE addition were evaluated.

* Number in paranthesses designate references at the end of the paper

(1) Gasoline aromatic contents and exhaust emissions.

TEST METHODS

Test Engines

L4 1.8l with carburetor and without catalitic converter

Test conditions

1500rpm, -420mmHg and 3000rpm, -340mmHg

Hydorocarbon composition Analisys

GASOLINE - FIA (ASTM 1319) and Gas Cromatography

EXHAUST GAS - Gas Cromatography

Exaust emission - direct sampling

Gasoline hydrocarbon types were classified into aromatics, olefins, and paraffins by FIA method.

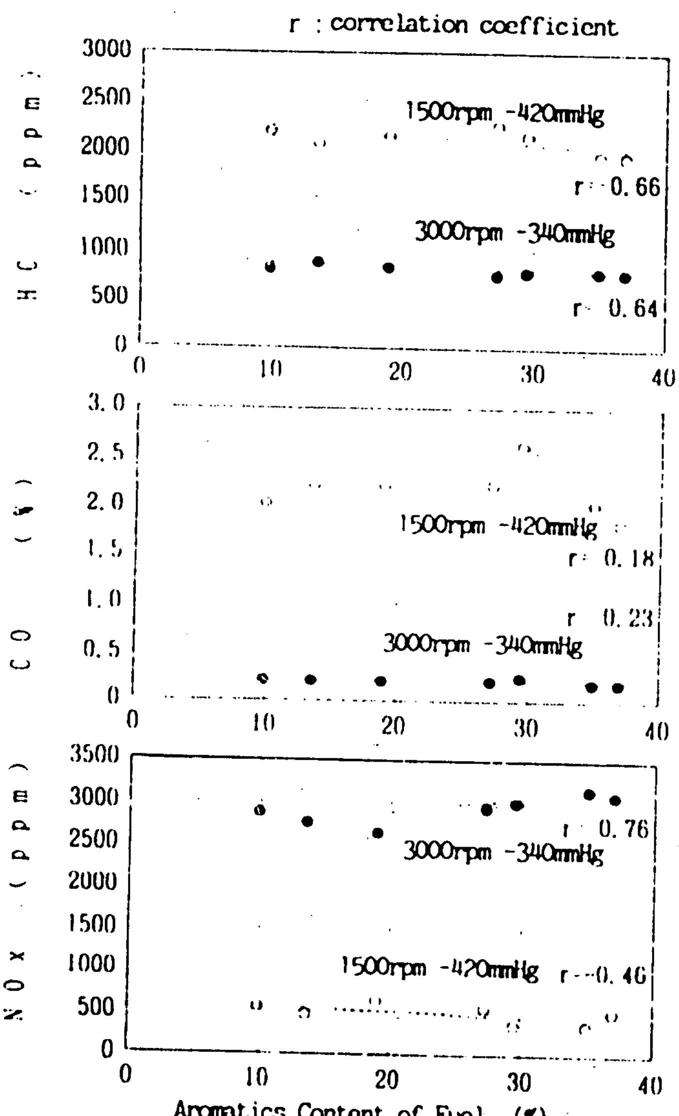


Fig. 1 Effect of Fuel Aromatics on Exhaust Emissions

A detailed analysis of composition was made by gas chromatography. Gasolines with similar properties and only varied aromatics content (Appendix A).

The effects on HC, CO, NOx and aldehyde exhaust emissions were studied. As part of the test, the hydrocarbon composition of exhaust HC was measured by gas chromatography to evaluate the exhaust HC photchemical reactibity by Caplan scale (6). To ensure more accurate measurement of the effects of the fuel, constant engine condition, mesurements were taken without catalitic converter.

Results indicate a slight decrease of exhaust HC and an increase of NOx incidental to the increase of fuel aromatics as shown in figs. 1. While HC decreased, exhaust photo chemical reactibity increased. (figs. 2).

Fig. 3 shows the relationship between the content of total aromatics in the fue (by FIA) and each aromatic in the exhaust gas (by GC). Exhaust aromatics fraction increase with the increase of fuel aromatic. Also Aromatics of photo-chemical reactivity Class Ⅲ ,Ⅳ (see Appendix B) increase. Consequently, photo-chemical reactivity of exhaust gas increase as a result of aromatics in fuel increase.

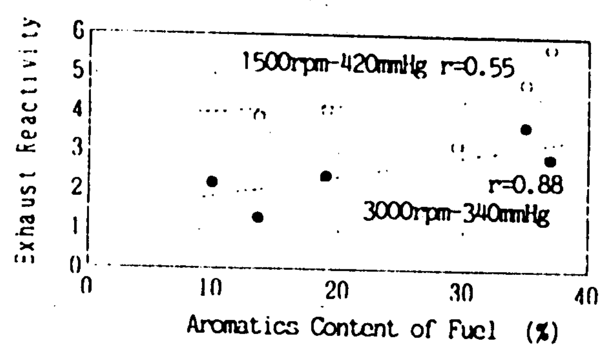


Fig. 2 Effect of Aromatics on Exhaust Reactivity

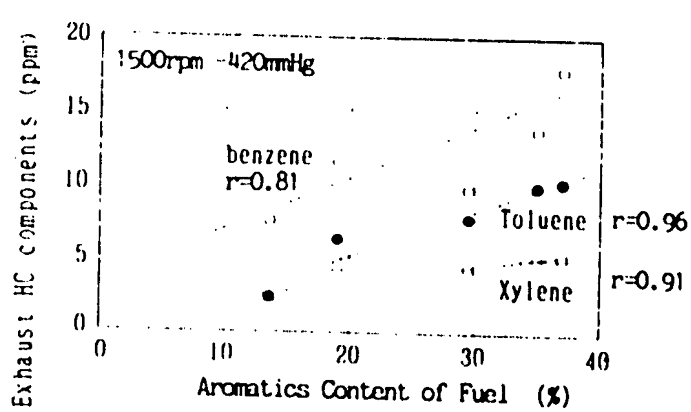


Fig.3 Correlation of Exhaust Components with Fuel Aromatics

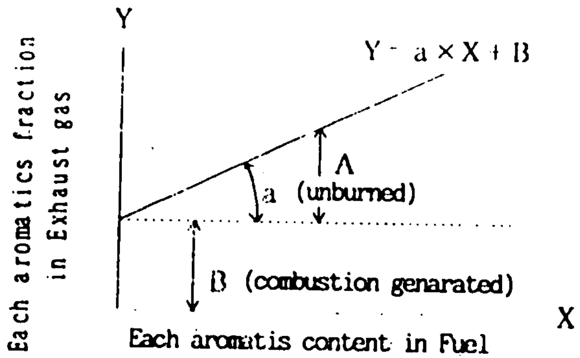


Fig. 4 Combustion generated and Unburned Aromatic

The relationship between aromatics in the fuel and those components in exhaust emissions was measured. It was then determind whether the individual hydrocarbons were discharged directly unburnt, reflecting the contents in fuel (value 'A' in fig. 4), or were generated in the combustion process, assuming the value when the fuel aromatics is zero by extraporation (value 'B' in fig. 4).

Table 1 shows the results between fuel and exhaust content of each aromatics. Some amount of Benzene is generated in the combustion process. Toluene and Xylene are generated in small amounts. It would be necessary to reduce the Benzene discharged in exhaust gas.

Table 1 Correlation between Exhaust and Fuel HC composition (Aromatics)

X:Content in Fuel(v%)
Y:content in Exhaust gas(ppm)
r:correlation coefficient

Benzene	Y = 0.75X + 3.4	r = 0.72
Toluene	Y = 0.075X + 1.8	r = 0.67
Xylene	Y = 0.2X + 0.1	r = 0.72

There were no definite indications of the effect of aromatics on the total amount of aldehyde in exhaust emissions. It varied with the engine load and speed as shown in fig. 5.

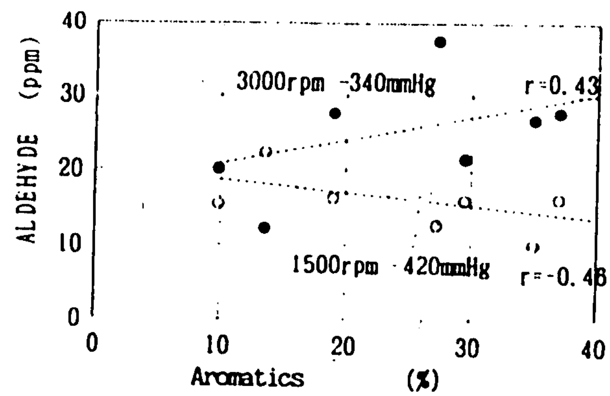


Fig. 5 Effect of Fuel Aromatics on Exhaust Aldehyde Emissions

(2) Gasoline volatility and exhaust emissions

The next step of testing was to measure the effect of gasoline volatility by using the gasolines in Appendix C, under the same test conditions as before. The test results are shown in fig. 6. When RVP increased, exhaust HC decreased slightly.

Similarly, distillation properties were studied. The results are shown in figs. 7 and 8. Gasoline with more light fraction (a high amount of distillates of up to 55 ℃) and gasoline with less amount of distillates of a high boiling point (a high amount of distillates of up to 150 ℃), indicate that changes in exhaust HC are small.

As a result of evaluating exhaust photo chemical reactibity with a Caplan scale, the fuel with a high amount of light fraction was found to have a slight reduction of exhaust reactibity as shown in fig. 8. From the results mentioned above, gasoline volatility, RVP and distillation somewhat influence exhaust emissions at constant engine speed conditions.

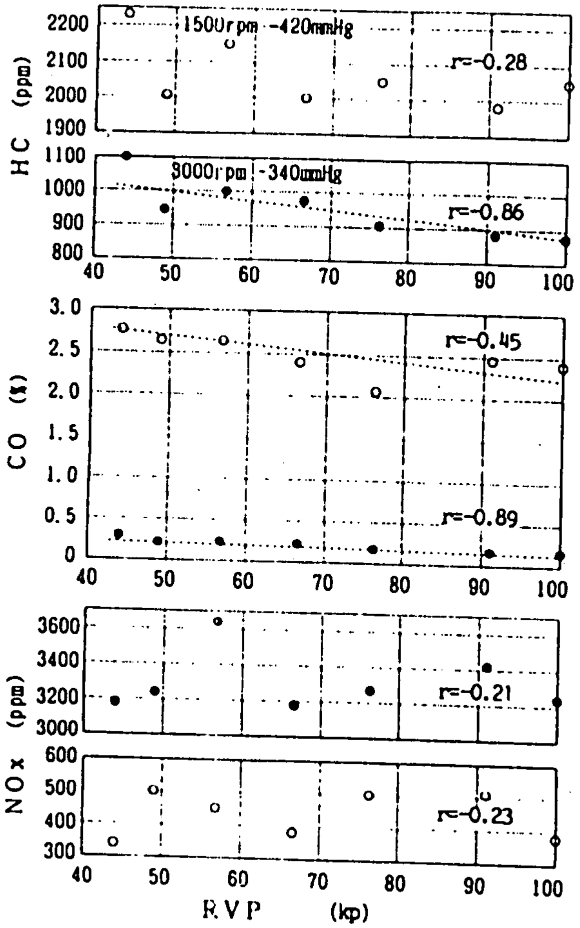


Fig.6 Effects of RVP on Exhaust Emissions

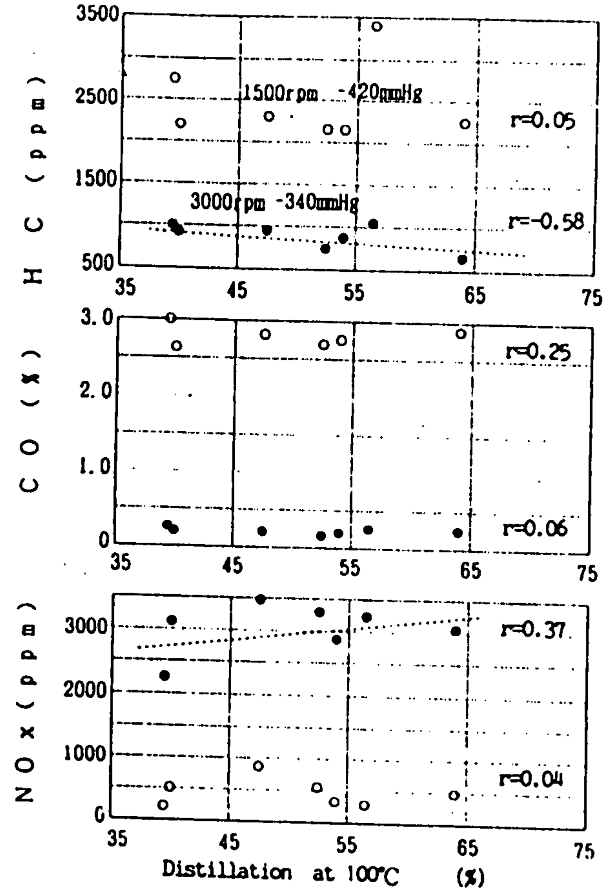


Fig.7 Effects of Distillation at 100 ℃ on Exhaust Emissions

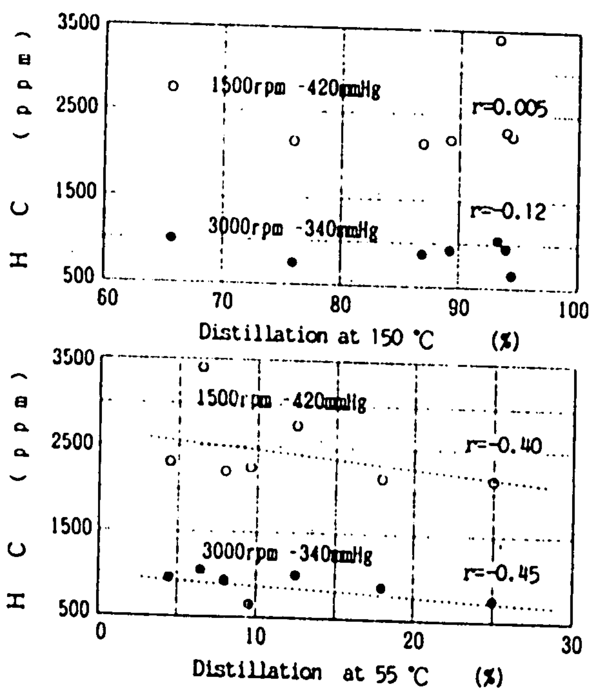


Fig. 8 Effects of Distillation at 150 ℃ and 55 ℃ on HC Emission

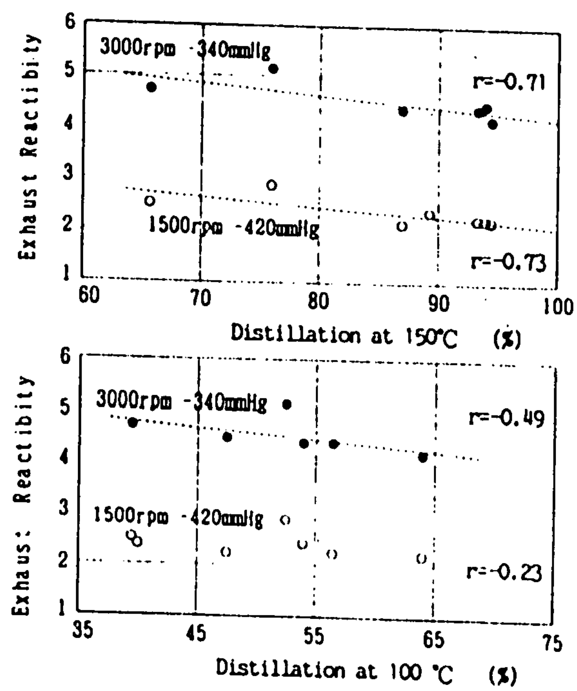


Fig. 9 Effects of Distillation at 150℃ and 100℃ on Exhaust reactivity

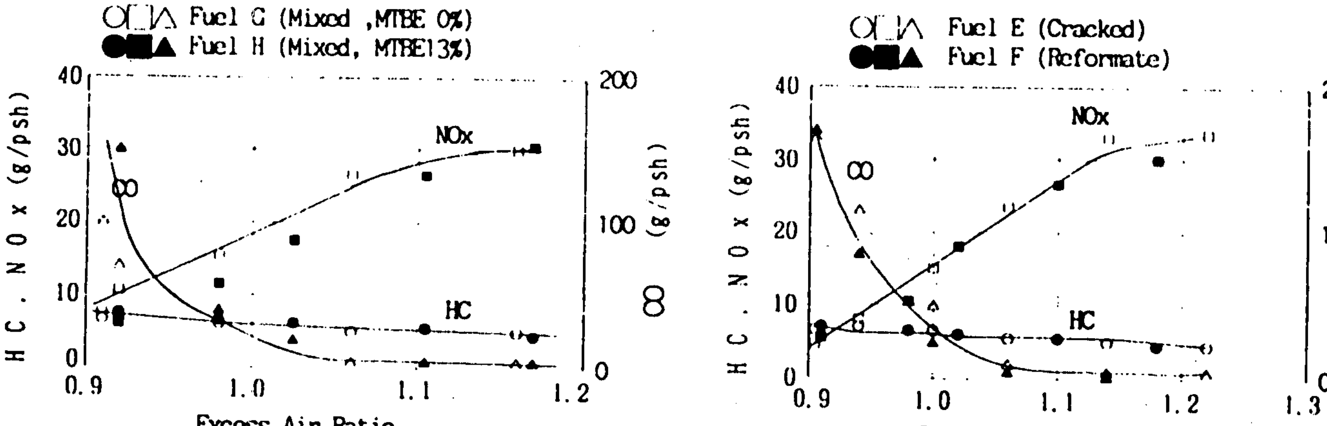


Fig.10 Exhaust Emissions of MTBE Blended Gasoline

(3) Effect of MTBE on exhaust emissions

The effect of MTBE, an oxygen-containing compound which in recent years has become a common gasoline blending component, was studied. It is possible that MTBE has combustion characteristics different from that of hydrocarbons. One of MTBE's characteristics is that it contains oxygen so that it leans the engine's intake of air/fuel mixture in open loop operation.

(i) CFR engine test

First, a detailed study was made on the effects of combinations of MTBE with gasoline components.

TEST METHODS
Test Engines
experimental single-cylinder engine (CFR-RDH)
Test conditions
1000rpm, 2kgf-m

An experimental single-cylinder engine (CFR-RDH) was used for the test, operating a 1000rpm- 2kgf-m. The test fuels, as shown in table 2 , were prepared by blending MTBE with catalyticaly cracking naphtha, reformate naphtha, and their mixture, which are base stocks of commercial gasoline.

Table 2 Test Fuel (2)

Fuel No.	E	F	G	H
Gasoline Blending Stocks	Cracked Naphtha	Reformate Naphtha	Mixed	Naphtha
MTBE %	10	10	0	13
RON	94.8	95.1	98.2	98.2
Aromatics %	23.5	45.5	48.5	34.5
Olefins %	37.5	0.5	17.0	18.0
RVP kp	51	41.5	45.1	53.4

As shown in fig. 10, no difference was obsrved in exhaust emissions among these fuels at the same excess air ratio. The only effect of MTBE blends are enleanment of the air/fuel ratio.

(ii) Vehicle equipped engine test

Next, using a vehicle equipped engine, fuels B and D (MTBE 15%) as shown in table 3 , were compared.

TEST ENGINE
L4, 1.6l with port fuel injection system and 3-way catalyst
EMISSION TEST PROCEDURE
LA #4 mode

As shown in fig. 11, in the case of catalytic converor inlet gas, the exhaust CO of fuel D is low while its NOx is high. This was caused mainly by a lean air/fuel ratio.

After catalyst conversion, however, that is, after exhaust gas processing by a 3-way catalyst system, there is little difference in the exhaust gas between the two fuels. Then, the oxygen sensor was removed and the feedback contorol was turned off. As before, catalyst inlet gas with fuel D was found to have low exhaust CO and High NOx. It was found from these results that, although the effects of MTBE are observed in the exhaust composition before catalytic convertor. MTBE has little effect on an engine having a feedback system and a 3-way catalytic convertor.

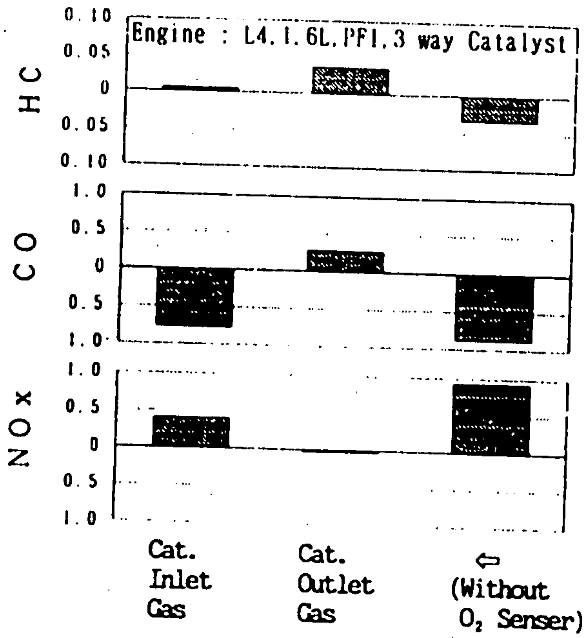


Fig. 11 Effect of MTBE Blends on Exhaust Emissions
(LA#4 Emission Difference Fuel D from Fuel B)

3. Vehicle Driveability and Exhaust Emissions

The test results indicated that the distillation properties and fuel composition would be important factors for reducing exhaust emissions. As already has been stated, the distillation properties have a great bearing on vehicle driveability. In this study, the relationship between driveability and the distillation properties of MTBE-blended gasoline were evaluated. The test was conducted on engine bench. The engine torque, with the throttle valve opened by 50% for one second, was measured as shown in fig. 12.

An engine bench test was used to evaluate the vhicle driveability. The experimental apparatus has a torque pick-up meter and an air fuel ratio meter. The coolant temperature was maintained at 25 ℃. To simulate transient condition during accelaration, the throttle valve was opend quickly. Detailed test method and test gasolines are shown in Appendix D.

Assuming that the time required for the torque to reach the specified value is the response time, its correlation with the 50% distillation point of gasoline was investigated as shown in fig.13. The results show that the response time of MTBE blend is longer than hydrocarbon type gasoline, even though the 50% distillation points are same. It is clear, therfore, that the distillation properties of MTBE blends should be formulated very carefully.

Table 3 Properties of test gasoline

Properties	Fuel A	Fuel B	Fuel C	Fuel D
Density g/ml	0.7655	0.7428	0.7342	0.7484
RVP kp	53.9	60.8	82.9	70.1
RON	97.2	91.5	91.4	95.4
Distilation ℃				
IBP	34.5	31.5	27.5	31.5
T10	58.5	53.0	43.0	48.5
T50	121.0	103.5	90.0	84.5
T90	170.0	156.5	161.0	169.0
EP	208.5	175.5	176.0	202.0
Aromatics v%	39.3	31.8	30.5	30.6
Olefins v%	9.0	5.1	14.5	7.2
MTBE v%	—	—	—	15.0

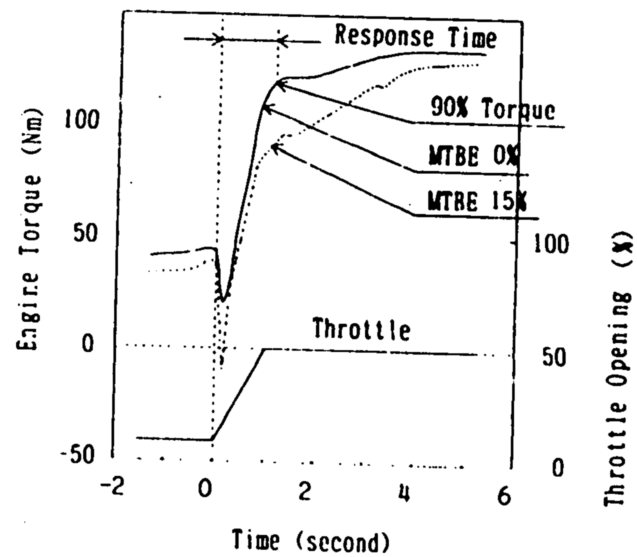


Fig. 12 Change in Torque on Engine Throttling

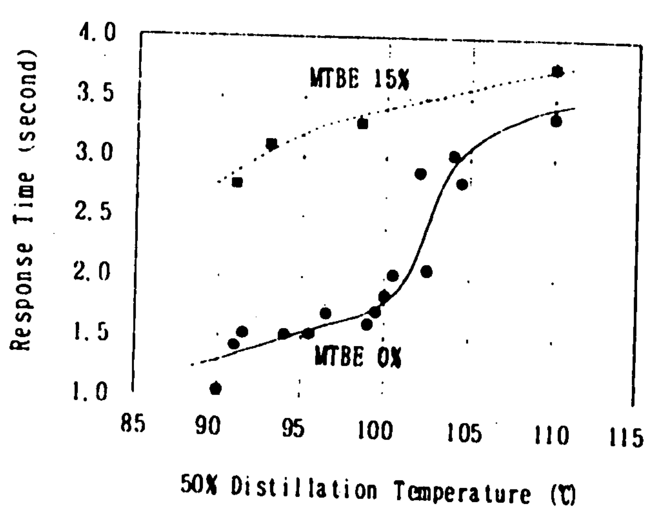


Fig. 13 Effect of MTBE Blends on Driveability

Distillation properties influence driveability, by creating an unstable air/fuel ratio under transient driving conditions. This instability affects the level of exhaust emissions, therfore, the relationship between exhaust emissions and driveability was investigated by using gasoline having different volatilities.

Driverbility is judged by hesitation during vhecle warm up. (Test method is shown in Appendix E) Three kinds of gasoline were used in the test as shown in table 3. Fuel A has a relatively low RVP and high 50% distillation temperature (T50 -- almost maximum value in the market in summer) (7), fuel C has a high RVP and a low T50 (minimum value in the market), and fuel B which has an average RVP and T50 (average in the market) that is halfway between fuel A and C. The test was performed by using a vehicle which had been driven for a total distance of 50,000 miles. As shown the results in fig. 14 , it was found that the fuel A emitted more HC and CO and less NOx than the fuel B or C . This indicats that there is a high correlation between driveability and exhaust emissions when gasoline T50's are changed. Distillation properties (mainly T50) of gasoline has a great bearing on vhicle driveability (3). According to the correration between dribeability and exhaust emissions, T50 would also affect on exhaust emissions, especialy HC and CO at transient driving conditions compared with constant speed conditions.

Fuel A is a high T50, with driveability degrading with a coresponding increase in exhaust HC and CO. When the air/fuel ratio was adjusted with the aim of improving the driveability for fuel A (high T50) to be equivalent to that for fuel B, exhaust HC and CO increase even more. That is, it would be considerably difficult to make vehicle driveability and exhaust emissions compatible if high midile-range distillation temperature gasoline is used.

4.CONCLUSION

Regarding the effects of the gasoline properties on exhaust emissions, the following findings were obtained as a result of a study that evaluated without catalytic convertor, under constant engine speed conditions.

(1) Effect of hydrocarbon composition

An increase in aromatics causes an increase in NOx and a decrease in HC and little change in exhaust photo chemical reactibity.

The aromatics content of the fuel is related to exhaust aromatic emissions, while benzene is also generated by the combustion of fuel aromatics.

(2) Effect of gasoline volatility

Under constant speed conditions, the effect of gasoline volatility on exhaust emissions is small.

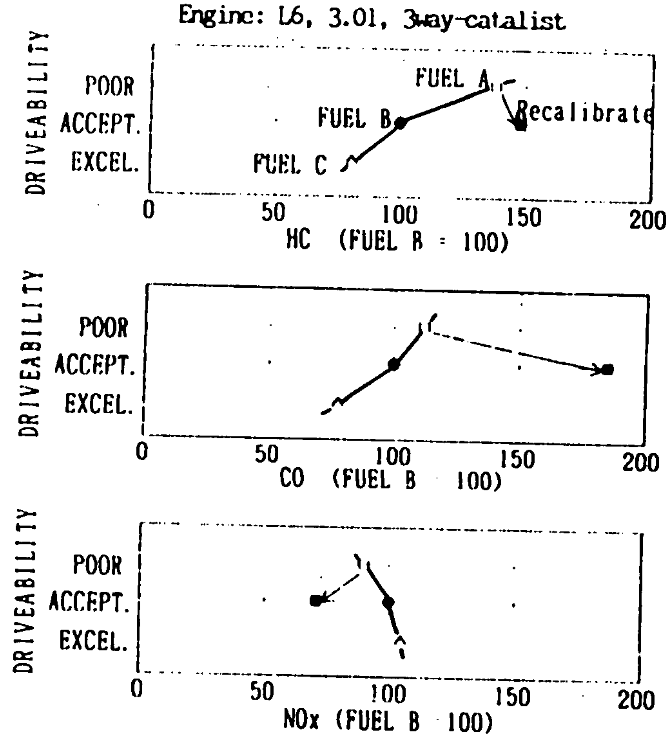


Fig.14 Correlation Between Exhaust Emission and Driveability

(3) Effect of MTBE blends

The mixture of MTBE with gasoline leans the air/fuel ratio, consequently decreasing HC and CO but increasing NOx. However, MTBE has little effect on an engine equipped with a feedback control system.

In transient driving conditions, the following was observed as a result of studying the relationship of gasoline volatility with vehicle driveability and exhaust emissions.

(1) The middle range of gasoline distillation temperature strongly affect vehicle driveability, and at the same time, affect exhaust HC and CO emissions.

(2) An attempt to adjust the engine to improve driveability results in a further increase of exhaust HC and CO emissions.

References

(1) Minoru Tomita, et al., SAE Paper 900163
(2) Noboru Kaneko, et al., SAE Paper 881669
(3) D.A.Baker, et al., SAE Paper 881668
(4) Patrick Crow, et al., Oil & Gas Journal Jan.23.1989 P.P.15-18
(5) J.M. Colucci GMR-7010, API Forum April 25.1990
(6) J.D.Caplan, et al., SAE Transactions, Vol.74,1966, P.P.20-31
(7) MVMA of U.S.A. Inc., National Fuel Survey Motor Gasoline Winter 1989

Appendix A

Table 4 Test Fuel for Aromatics Evaluation

Fuel No.	1	2	3	4	5	6	7
RVP (kp)	62	62	64	62	67	76	75
Aromatics %	9.9	13.6	19.0	27.3	29.5	35.0	37.0
Olefins %	9.5	12.1	10.7	11.9	11.3	10.9	12.5
Distillation Evaporated							
@50°C %	11.2	10.0	12.0	11.2	16.0	10.5	13.0
@100°C %	51.5	50.2	51.8	51.5	93.2	48.5	49.2
@180°C %	86.0	87.5	90.0	90.0	90.0	93.0	96.0
RON	91	91	91	91	91	91	91
Oxygenates %	0	0	0	0	0	0	0

Appendix B

Table 5 Hydrocarbon Reactivity Classes and Class Specific Reactivity

Class	Hydrocarbon	Specific Reactivity
I	Methane, Ethane, Propane, Acetylens Benzene	0
II	Mono alkyl benzen, C_3 & higher paraffins, Cyclic paraffins Ortho & para dialkyl benzenes	2
III	Ethylene, Meta dialkyl benzenes Form ldehyde & higher aldehydes	5
IV	1-olefins, DiOlefins Tri & tetra alkyl benzenes	10
V	Internally bonded olefins	30
VI	Internally bonded olefins with substitution at the double bond Cyclo olefins	100

Exhaust Reactivity = $\Sigma\ (M_i \times R_i)$

M_i : Mole fraction of each hydrocarbon

R_i : Specific reactivity of each hydrocarbon

Appendix C

Table 6 Test Fuels for RVP Evaluation

Fuel No.	1	2	3	4	5	6	7
RVP (kp)	43	49	57	67	76	91	101
Aromatics %	23.1	33.8	39.7	32.0	30.8	41.5	39.7
Olefins %	10.7	12.9	9.2	8.1	3.8	10.9	6.8
Distillation Evaporated							
@50 °C %	15.0	5.0	3.5	5.5	7.5	15.5	8.5
@100°C %	56.0	47.0	42.0	44.0	46.0	47.5	36.0
@180°C %	94.0	90.5	93.5	92.5	94.0	94.0	90.0
RON	91	91	91	91	91	91	91
Oxygenates %	0	0	0	0	0	0	0

Table 7 Test Fuels for Distillation Evaluation

Fuel No.	1	2	3	4	5	6	7
RVP (kp)	59	62	53	61	65	46	61
Aromatics %	16.4	33.1	28.0	28.7	30.2	46.1	35.3
Olefins %	10.4	7.4	3.6	6.3	4.9	1.0	10.4
Distillation Evaporated							
@55 °C %	18.0	12.5	9.6	6.5	8.0	4.5	25.0
@100°C %	54.0	39.5	64.0	56.5	40.0	47.5	52.5
@150°C %	87.0	65.7	94.5	93.3	89.3	94.0	76.0
RON	91	91	91	91	91	91	91
Oxygenates %	0	0	0	0	0	0	0

Appendix D

Experimental Method of Driveability (Engine Response)

1. Experimental Apparatus

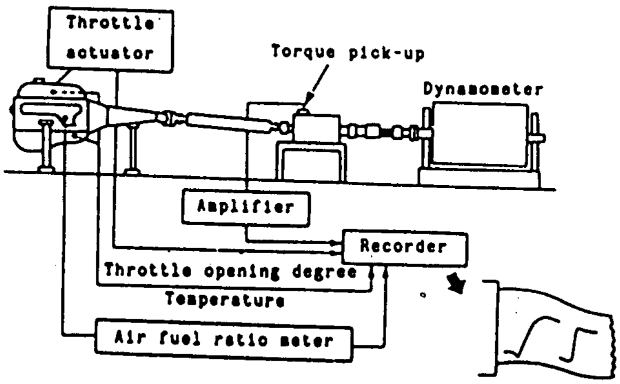


Figure . Experimental Apparatus

2. Test Engine
   - Cylinder Arrangement : L4
   - Displacement (L) : 2.0
   - Fuel System : PFI
   - Combustion Chamber : Pent Roof (4 Valve/Cylinder)

3. Test Condition
   - Engine Coolant Temperature (°C) : 25
   - Engine Speed (rpm) : 1400-Constant
   - Throttle Valve Openning : Road-Load

   Road-Load (Manifold Vacuum = -58kPa)

   ↓ (1.0 second)

   50% Openning

4. Measuring Items
   - Engine Torque
   - Air Fuel Ratio
   - Engine Speed
   - Manifold Vacuum
   - Throttle Valve Openning Angle
   - Engine Coolant Temperature

5. Test Gasolines

Gasoline NO.	1	2	3	4	5	6	7	8	9	10
RVP Kpa	71.5	65.7	71.5	61.7	66.2	65.2	65.2	74.5	71.5	83.3
T10 ℃	48.0	50.5	47.0	53.5	52.0	50.5	51.0	47.0	47.5	42.0
T50 ℃	91.5	99.0	91.0	100.5	95.5	104.0	102.5	99.5	96.5	100.0
T90 ℃	152.0	159.0	152.0	152.5	142.0	155.0	153.0	162.0	162.0	162.5
E70 %	32.3	27.8	32.9	24.4	27.6	26.3	25.7	31.2	31.6	33.4
MTBE %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gasoline NO.	11	12	13	14	15	16	17	18	19
RVP Kpa	84.8	57.5	61.8	56.9	59.8	60.8	60.8	72.1	74.5
T10 ℃	41.0	54.0	53.0	58.0	57.0	54.5	54.0	50.0	49.5
T50 ℃	94.0	90.5	104.5	110.0	110.0	99.0	102.0	90.0	93.0
T90 ℃	163.0	157.0	160.5	156.0	157.5	152.0	154.0	146.0	165.0
E70 %	35.7	31.7	25.4	18.6	19.3	24.8	22.8	32.0	27.3
MTBE %	0.0	15.0	0.0	0.0	15.0	15.0	0.0	0.0	15.0

Appendix E

Test Method of Driveability

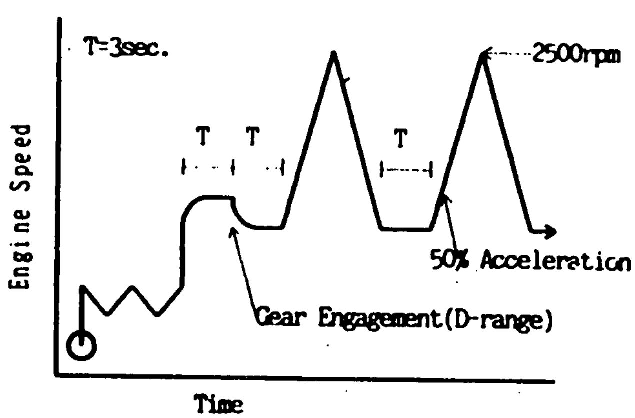


Fig.1 Driving Pattern

Driveability Judgment

Level	Hesitasion
Excelent	None
Acceptable	Trace
Poor	Modelate & Heavy

Test Vehicle

Model Year	: '89
Engine Type	: L6
Displacement(L)	: 3.0
Fuel System	: PFI
Transmission	: 4AT

91. [redacted] A method for operating an automotive vehicle that [redacted] aids in minimizing the amount of at least one gaseous pollutant selected from the group consisting of NOx, CO, and hydrocarbons in the exhaust emissions discharged into the atmosphere, the automotive vehicle having a spark-induced, internal combustion engine and a catalytic converter, the method comprising:

[redacted] (1) introducing into the engine an unleaded gasoline having

(a) a Reid Vapor Pressure less than 7.0 psi,

(b) a 50% D-86 distillation point no greater than 210° F.,

(c) an olefin content less than [redacted] 10 vol.%,

(d) a 90% D-86 distillation point less than 300° F., and

(e) an octane value of at least 87;

and thereafter

(2) combusting the unleaded gasoline in said engine;

(3) [redacted] contacting at least some of the resultant engine exhaust emissions with the catalytic converter; and

(4) [redacted] discharging the exhaust emissions from the catalytic converter to the atmosphere.

92. [redacted] A method as defined in claim 91 wherein the unleaded gasoline has an olefin content less than [redacted] 8 volume percent.

94. [redacted] A method as defined in claim 91 [redacted] wherein the gasoline has a Reid Vapor Pressure no greater than 6.8 psi and a maximum D-86 10% Distillation Point of 140° F.

95. A method as defined in claim 94 wherein the Reid Vapor Pressure of the unleaded gasoline is no greater than 6.5 psi.

96. [redacted] A method for reducing the amount of at least one gaseous pollutant emitted in automotive exhaust emissions, comprising:

[redacted] (1) introducing into a spark-induced automotive internal combustion engine in an automotive vehicle equipped with a catalytic converter for treating exhaust emissions, an unleaded gasoline having

(a) a Reid Vapor Pressure less than 7.0 psi,

(b) a 50% D-86 distillation point no greater than 210° F.,

(c) an olefin content less than 10 vol.%,

(d) a 90% D-86 distillation point less than 300° F.,

(e) an octane value of at least 87; and

(f) a 10% D-86 distillation point no greater than 158° F.;

and

[redacted] (2) combusting the gasoline in said engine to yield exhaust emissions, which, after treatment in the catalytic converter, have, in comparison to combusting according to the Federal Test Procedure a fuel having the properties for blend A/O AVE shown in TABLE 2, a reduced amount of at least one gaseous pollutant selected from the group consisting of NO_x, CO, and unburned hydrocarbons.

98. [redacted] A method as defined in claim 91 [redacted] wherein the unleaded gasoline has [redacted] a D-86 10% Distillation point no greater than [redacted] 140° F. [redacted]

99. [redacted] A method as defined in claim 91 wherein the unleaded gasoline has [redacted] an olefin content less than [redacted] 6 volume percent.

100. [redacted] The method [redacted] of claim 91, 94, 96 or 99 in which the unleaded gasoline being combusted in said engine contains one or more added oxygenates and meets all the requirements of at least

one of the Class A, Class B, Class C, Class D, and Class E gasolines set forth in TABLE 1.

101. The method of claim 100 resulting in the reduction of NO_x emitted in the exhaust emissions from said catalytic converter.

102. The method of claim 100 resulting in the reduction of unburned hydrocarbons emitted in the exhaust emissions from said catalytic converter.

103. The method of claim 100 resulting in the reduction of CO emitted in the exhaust emissions from said catalytic converter.

104. The method of claim 100 wherein said catalytic converter is a three-way catalytic converter, and the total measured amount of NO_x, CO, and hydrocarbons emitted from said converter is reduced by at least 10% in comparison to fuel A/O AVE in Table 2 when combusted in the same engine under the same conditions as said unleaded gasoline according to the Federal Test Procedure.

105. [redacted] The method of claim 100 wherein said unleaded gasoline contains one or more oxygenates in a total oxygen concentration between the equivalent of about 10.1 and [redacted] 14.9 vol.% methyl tertiary butyl ether.

106. [redacted]) [redacted];

[redacted]

[redacted] The method of claim 105 wherein said unleaded gasoline contains greater than 65 volume percent paraffins.

107. [redacted] The method of claim [redacted] 105 wherein said unleaded gasoline contains greater than 72 volume percent paraffins.

108. [redacted] The method of claim [redacted] 100 wherein said unleaded gasoline contains greater than 65 volume percent paraffins.

117. [redacted] A method of aiding in [redacted] minimizing air pollution caused by [redacted] automobiles comprising the steps of:

(1) producing in an oil refinery a substantial amount of [redacted] unleaded gasoline selected from the group consisting of:

(a) unleaded gasolines having a Reid Vapor Pressure less than 7.0 psi, an octane value of at least 87, a 50% D-86 distillation point no greater than 210 °F, and a paraffin content greater than 72 volume percent;

(b) unleaded gasolines having a Reid Vapor Pressure less than 7.0 psi, an octane value of at least 92, a 50% D-86 distillation point no greater than 210 °F, and a paraffin content greater than 65 volume percent;

(c) unleaded gasolines having a Reid Vapor Pressure less than 7.0 psi, an octane value of at least 87, a 50% D-86 distillation point less than 193 °F, and an olefin content less than 10 volume percent;

(d) unleaded gasolines having a Reid Vapor Pressure less than 7.0 psi, an octane value of at least 87, a 50% D-86 distillation point no greater than 210 °F, and an olefin content less than 1 volume percent; and

(e) unleaded gasolines having a Reid Vapor Pressure less than 7.0 psi, an octane value of at least 87, a 50% D-86 distillation point no greater than 210 °F, an olefin content less than 10 volume percent, and a 90% D-86 distillation point less than 300 °F. [[redacted];

(2) delivering said unleaded gasoline to a substantial number of gasoline service stations distributed within a geographical [redacted] region with significant air pollution caused in substantial part by the emission of exhaust gases from the operation of automobiles within said region; and

(3) dispensing the unleaded gasoline from said gasoline service stations into a substantial number of automobiles for subsequent combustion therein, said automobiles having catalytic converters for treating exhaust emissions.

118. The method of claim 117 performed during a time period of one month wherein the amount of said unleaded gasoline dispensed in step (3) during said month is the equivalent of at least 100,000 gallons of gasoline per day.

119. The method of claim 117 performed during a time period of one week wherein the amount of said unleaded gasoline dispensed in step (3) during said week is at least 10,000,000 gallons of gasoline.

120. The method of claim 117 wherein the amount of said unleaded gasoline dispensed in step (3) over the course of one month is equivalent to at least 25% of the amount dispensed by all service stations in said region for said month.

121. The method of claim 117, 118, 119, or 120 wherein said gasoline produced in step (1) is gasoline (a).

122. The method of claim 121 wherein the gasoline produced in step (1) has an olefin content less than 10 volume percent and a 90% D-86 distillation point no greater than 315 °F.

123. The method of claim 122 wherein the gasoline produced in step (1) has an olefin content less than 6 volume percent.

124. The method of claim 122 wherein the gasoline produced in step (1) has a 50% D-86 distillation point less than 200 °F.

125. The method of claim 117, 118, 119, or 120 wherein said gasoline produced in step (1) is gasoline (b).

126. The method of claim 125 wherein the gasoline produced in step (1) has an olefin content less than 6 volume percent and a 90% D-86 distillation point no greater than 315 °F.

127. The method of claim 126 wherein the gasoline produced in step (1) has a 50% D-86 distillation point less than 200 °F.

128. [redacted] The method of claim 117 [redacted] or 119 [redacted] wherein said gasoline produced in step (1) is gasoline (c).

129. The method of claim 128 wherein the gasoline produced in step (1) has an olefin content less than 6 volume percent and a 90% D-86 distillation point no greater than 315 °F.

130. The method of claim 129 wherein the gasoline produced in step (1) has a paraffin content greater than 65 volume percent.

131. [redacted] The method of claim 117 [redacted] wherein said gasoline produced in step (1) is gasoline (d).

132. The method of claim 131 wherein said gasoline (d) has a paraffin content greater than 65 volume percent and a 90% D-86 distillation point less than 300 °F.

133. The method of claim 117, 118, 119, or 120 wherein said gasoline produced in step (1) is gasoline (e).

134. [redacted] The method of claim 133 wherein said unleaded gasoline produced in step (1) contains one or more oxygenates in a total oxygen concentration between the equivalent of about 10.1 and [redacted] 14.9 vol.% methyl tertiary butyl ether.

135. [redacted] The method of claim [redacted] 134 wherein the gasoline produced in step (1) has a paraffin content greater than 65 volume percent.

136. [redacted] The method of claim [redacted] 134 wherein said unleaded gasoline produced in step (1) contains less than 8 volume percent olefins [redacted].

137. [redacted] The method of claim 136 wherein said unleaded gasoline produced in step (1) contains less than 6 volume percent olefins but more than 72 volume percent paraffins.

138. [redacted] The method of claim [redacted] 117, 118, 119, or 120 wherein said unleaded gasoline produced in step (1) contains [redacted] one or more added oxygenates.

139. [redacted] The method of claim [redacted] 117, 118, 119, or 120 wherein [redacted] said unleaded gasoline produced in step (1) [redacted] contains one or more oxygenates in a total oxygen concentration between the equivalent of about 10.1 and 14.9 vol.% methyl tertiary butyl ether.

142. [redacted]) A method for [redacted]] aiding in minimizing the amount of at least one gaseous pollutant selected from the group consisting of NOx, CO, and hydrocarbons emitted in automotive exhaust emissions, comprising:

(1) introducing, into a spark-induced automotive internal combustion engine in an automotive vehicle equipped with a catalytic converter for treating exhaust emissions, an unleaded gasoline selected from the group consisting of:

(a) unleaded gasolines having a Reid Vapor Pressure less than 7.0 psi, an octane value of at least 87, a 50% D-86 distillation point no greater than 210 °F, and a paraffin content greater than 72 volume percent;

(b) unleaded gasolines having a Reid Vapor Pressure less than 7.0 psi, an octane value of at least 92, a 50% D-86 distillation point no greater than 210 °F, and a paraffin content greater than 65 volume percent;

(c) unleaded gasolines having a Reid Vapor Pressure less than 7.0 psi, an octane value of at least 87, a 50% D-86 distillation point less than 193 °F, and an olefin content less than 10 volume percent;

(d) unleaded gasolines having a Reid Vapor Pressure less than 7.0 psi, an octane value of at least 87, a 50% D-86 distillation point no greater than 210 °F, and an olefin content less than 1 volume percent; [redacted]

(e) unleaded, oxygenated gasolines having a Reid Vapor Pressure less than [redacted] 7.5 psi, an octane value of at least 87, a 10% D-86 distillation point no greater than 158 °F, a 50% D-86 distillation point no greater than [redacted] 215 °F, a 90% D-86 distillation point no greater than 315 °F., a paraffin content greater than 65 volume percent, and an olefin content less than 10 volume percent [[redacted];

(f) unleaded, oxygenated gasolines of octane value at least 87 with a Reid Vapor Pressure less than 7.0 psi, a 10% D-86 distillation point no greater than 158° F., a paraffin content greater than 65 volume percent, and a 50% D-86 distillation point

no greater than 215 °F.;

(g) unleaded, oxygenated gasolines of octane value at least 87 with a Reid Vapor Pressure less than 7.0 psi, a 10% D-86 distillation point no greater than 158° F., and a paraffin content greater than 70 volume percent; and

(h) unleaded, oxygenated gasolines of octane value at least 87 with a Reid Vapor Pressure less than 7.0 psi, a 10% D-86 distillation point no greater than 158° F., a 50% D-86 distillation point no greater than 215 °F, an olefin content less than 10 volume percent, and the oxygenates are present in a total oxygen concentration no greater than the equivalent provided by about 14.9 volume percent methyl tertiary butyl ether;

(2) combusting the gasoline in said engine, and

(3) passing emissions from said engine through the catalytic converter to be treated therein.

143. The method of claim 142 wherein the gasoline introduced into said engine is unleaded gasoline (a).

144. The method of claim 142 wherein the gasoline introduced into said engine is unleaded gasoline (b).

145. The method of claim 142 wherein the gasoline introduced into said engine is unleaded gasoline (c).

146. The method of claim 142 wherein the gasoline introduced into said engine is unleaded gasoline (d).

147. The method of claim 142 wherein the gasoline introduced into said engine is unleaded gasoline (e).

148. [redacted] The method of claim 147 wherein said unleaded gasoline [redacted] has a 90% D-86 distillation point no greater than 300° F.

149. [redacted] The method of claim 143 or 144 [redacted] wherein said unleaded gasoline contains less than 6 volume percent olefins and the 90% D-86 distillation point is no greater than 315°F.

150. [redacted] The method of claim [redacted] 147 wherein said unleaded gasoline contains one or more oxygenates in a total oxygen concentration between the equivalent of about 10.1 and 14.9 vol.% methyl tertiary butyl ether.

151. The method of claim 150 wherein the unleaded gasoline contains greater than 72 volume percent paraffins.

152. The method of claim 150 wherein the Reid Vapor Pressure is less than 7.0 psi.

153. The method of claim 152 wherein the unleaded gasoline contains greater than 72 volume percent paraffins.

154. A method of aiding in minimizing air pollution caused by automobiles comprising the steps of:

(1) producing in an oil refinery a substantial amount of unleaded, oxygenated gasoline selected from the group consisting of

(a) unleaded, oxygenated gasolines of octane value at least 87 with a Reid Vapor Pressure less than 7.5 psi, a 10% D-86 distillation point no greater than 158° F., a 50% D-86 distillation point no greater than 215 °F., a 90% D-86 distillation point no greater than 315 °F., a paraffin content greater than 65 volume percent, and an olefin content less than 10 volume percent;

(b) unleaded, oxygenated gasolines of octane value at least 87 with a Reid Vapor Pressure less than 7.0 psi, a 10% D-86 distillation point no greater than 158° F., a paraffin content greater than 65 volume percent, and a 50% D-86 distillation point no greater than 215 °F.;

(c) unleaded, oxygenated gasolines of octane value at least 87 with a Reid Vapor Pressure less than 7.0 psi, a 10% D-86 distillation point no greater than 158° F., and a paraffin content greater than 70 volume percent; and

(d) unleaded, oxygenated gasolines of octane value at least 87 with a Reid Vapor Pressure less than 7.0 psi, a 10% D-86 distillation point no greater than 158° F., a 50% D-86 distillation point no greater than 215 °F., an olefin content less than 10 volume percent, and the oxygenates are present in a total oxygen concentration no greater than the equivalent provided by about 14.9 volume percent methyl tertiary butyl ether;

(2) delivering said unleaded gasoline to a substantial number of gasoline service stations distributed within a geographical region with significant air pollution caused in substantial part by the emission of exhaust gases from the operation of automobiles within said region; and

(3) dispensing the unleaded gasoline from said gasoline service stations into a substantial number of automobiles for subsequent combustion therein, said automobiles having catalytic converters for treating exhaust emissions.

155. The method of claim 154 wherein the gasoline produced in step (1) is gasoline (a).

156. The method of claim 155 wherein the gasoline produced in step (1) comprises greater than 72 volume percent paraffins.

157. The method of claim 154 wherein the gasoline produced in step (1) is gasoline (b).

158. The method of claim 154 wherein the gasoline produced in step (1) is gasoline (c).

159. The method of claim 154 wherein the gasoline produced in step (1) is gasoline (d).

160. The method of claim 159 wherein the gasoline produced in step (1) has a 50% D-86 distillation point no greater than 210° F.

161. The method of claim 159 wherein the gasoline produced in step (1) has a paraffin content greater than 65 volume percent.

162. The method of claim 161 wherein said unleaded gasoline produced in step (1) contains less than 6 volume percent olefins.

163. The method of claim 162 wherein said unleaded gasoline produced in step (1) has a paraffin content greater than 72 volume percent.

164. The method of claim 117, 157, 158, 159, 161, or 163 wherein the 90% D-86 distillation point of said gasoline produced in step (1) is no greater than 315 °F.

165. The method of claim 164 wherein the 10% D-86 distillation point of said gasoline produced in step (1) is no greater than 140 °F.

166. The method of claim 165 wherein the Reid Vapor Pressure of said unleaded gasoline is no greater than 6.8 psi.

167. The method of claim 166 wherein the 50% D-86 distillation point of said gasoline produced in step (1) is less than 200 °F.

168. The method of claim 166 wherein the 10% D-86 distillation point of said gasoline produced in step (1) is no

greater than 135° F.

169. The method of claim 168 wherein the 50% D-86 distillation point of said gasoline produced in step (1) is less than 200 °F.

170. The method of claim 154, 159, 161 or 163 performed during a time period of one month wherein the amount of said unleaded gasoline dispensed in step (3) during said month is the equivalent of at least 100,000 gallons of gasoline per day.

171. The method of claim 170 wherein the 90% D-86 distillation point of said gasoline produced in step (1) is no greater than 315 °F.

172. The method of claim 154, 155, 157, 158, 159, 160, or 163 performed during a time period of one week wherein the amount of said unleaded gasoline dispensed in step (3) during said week is at least 10,000,000 gallons of gasoline.

173. The method of claim 172 wherein the 10% D-86 distillation point of said gasoline produced in step (1) is no greater than 140 °F. and the 90% D-86 distillation point of said gasoline produced in step (1) is no greater than 315 °F.

174. The method of claim 154 wherein the amount of said unleaded gasoline dispensed in step (3) over the course of one month is equivalent to at least 25% of the amount dispensed by all service stations in said region for said month.

175. The method of claim 117, 154, 155, 157, 158, 159, 160, 161, or 163 wherein, over a six month time period, the amount of said unleaded gasoline produced in step (1) is the

equivalent of at least 25% of the total of the refinery's daily gasoline production over said six month time period.

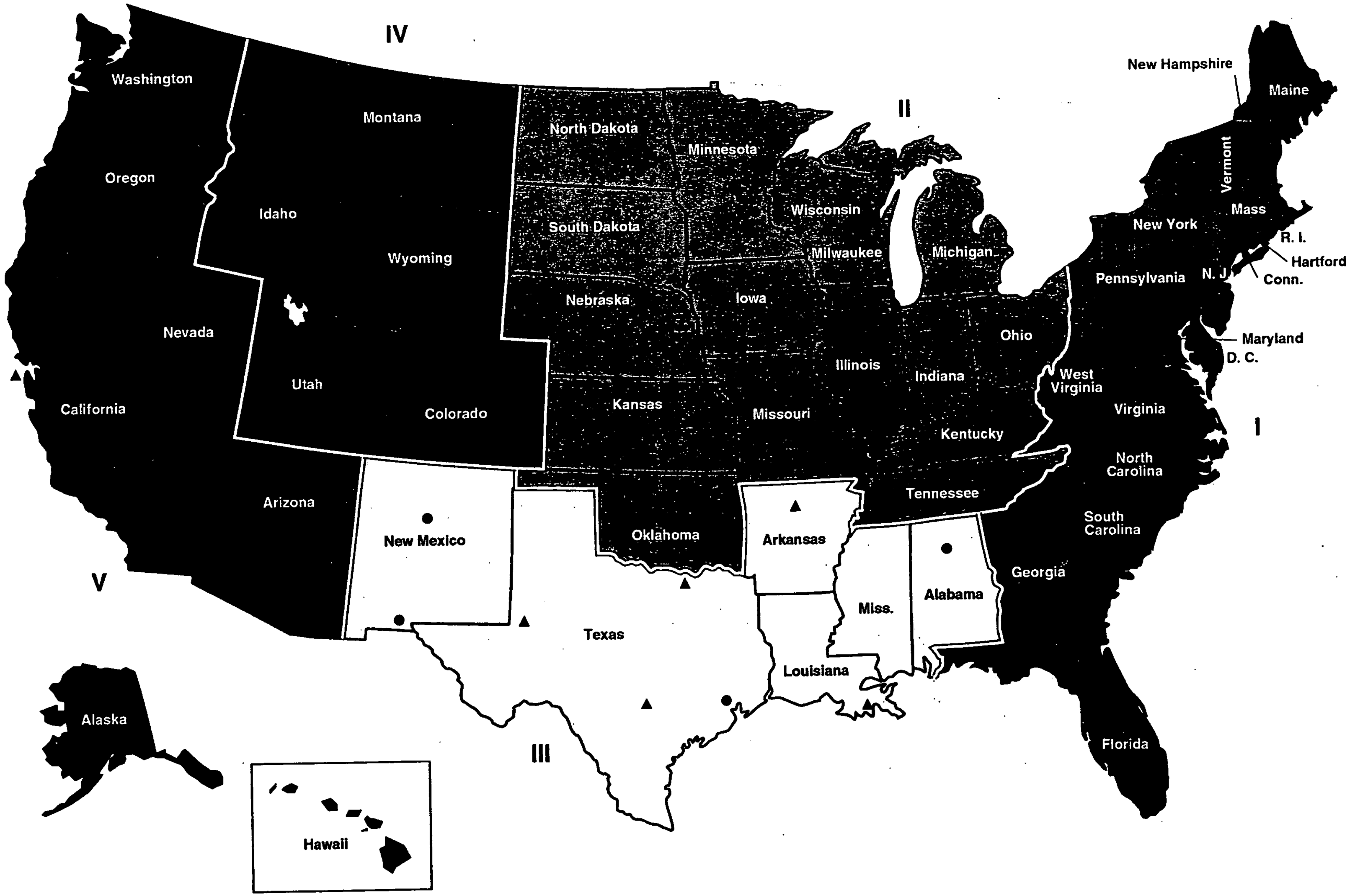
176. The method of claim 175 wherein the 90% D-86 distillation point of said gasoline produced in step (1) is no greater than 315 °F. and the 10% D-86 distillation point of said gasoline produced in step (1) is no greater than 140 °F.

177. The method of claim 176 wherein the 90% D-86 distillation point of said gasoline produced in step (1) is no greater than 300 °F.

178. The method of claim 142 wherein the gasoline introduced into said engine is unleaded, oxygenated gasoline (f).

179. The method of claim 142 wherein the gasoline introduced into said engine is unleaded, oxygenated gasoline (g).

180. The method of claim 142 wherein the gasoline introduced into said engine is unleaded, oxygenated gasoline (h).


IV
II
I
V
III
Washington
Oregon
California
Nevada
Arizona
Idaho
Montana
Wyoming
Utah
Colorado
New Mexico
North Dakota
South Dakota
Nebraska
Kansas
Oklahoma
Texas
Minnesota
Iowa
Missouri
Arkansas
Louisiana
Wisconsin
Milwaukee
Illinois
Michigan
Indiana
Ohio
Kentucky
Tennessee
Miss.
Alabama
West Virginia
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North Carolina
South Carolina
Georgia
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Pennsylvania
New York
Vermont
New Hampshire
Maine
Mass
R. I.
Hartford
Conn.
N. J.
Maryland
D. C.
Alaska
Hawaii